ANATOMY,

DESCRIPTIVE AND SURGICAL.

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A REVISED AMERICAN, FROM THE FIFTEENTH ENGLISH, EDITION.

WITH 780 ILLUSTRATIONS, MANY OF WHICH ARE NEW.

LEA BROTHERS & CO.,
PHILADELPHIA AND NEW YORK.
1901.

WESTCOTT & THOMSON,
Stereotypers and Electrotypers, Philada.

WILLIAM J. DORNAN,
Printer, Philada.

TO

SIR BENJAMIN COLLINS BRODIE, BART.,

F.R.S., D.C.L.,

SERJEANT-SURGEON TO THE QUEEN,

CORRESPONDING MEMBER OF THE INSTITUTE OF FRANCE,

This Work is Dedicated

IN ADMIRATION OF

HIS GREAT TALENTS

AND IN REMEMBRANCE OF

MANY ACTS OF KINDNESS SHOWN TO THE AUTHOR

FROM AN

EARLY PERIOD OF HIS PROFESSIONAL CAREER.

PUBLISHERS' NOTE TO THE NEW AMERICAN EDITION.

In his masterpiece Henry Gray left undying evidence of his anatomical knowledge and of his comprehension of the best method of imparting it to other minds. It is appropriate that a new and thoroughly revised edition of such a work should appear in the opening of the new century—for forty-five years it has easily held the front place among works on Anatomy, and its merits are only brightened by the numerous works which have endeavored to contest its supremacy. During that time it has had the benefit of the careful scrutiny of many leading anatomists of the English-speaking race. Anatomy is far from stationary, either in its facts or in improvements in the method of their presentation; hence any work which would faithfully reflect the existing position of the science must be revised at comparatively frequent intervals. Fortunately for students and practitioners, *Gray's Anatomy* enjoys a continuous demand rendering frequent revision possible.

The splendid illustrations in *Gray* have long been known as the most effective and intelligible presentations of anatomical structures ever produced. In the present revision this series has been vastly improved, special attention having been given to those for the portion on General Anatomy and Embryology.

The practical application of anatomical facts in medicine and surgery has always been a prominent feature of the work, and this distinctive characteristic has received especial care.

This *new century* edition is presented to the medical public with the absolute confidence that it will be found worthy in every respect to maintain the exalted position which the work has for so many years enjoyed as the most convenient and intelligible exposition of its subject.

PREFACE TO THE FIFTEENTH ENGLISH EDITION.

In this edition the entire work has undergone a careful revision. The section on Embryology has been somewhat amplified, and its text rendered more intelligible by the introduction of some sixty additional illustrations after His, Kollmann, Duval, and others. Throughout the rest of the work a considerable number of the diagrams have been redrawn and new illustrations here and there added.

The Editors are indebted to Dr. R. Bolam, Lecturer on Physiology and Histology, and to Dr. W. Turnbull, Demonstrator of Anatomy, both of the University of Durham College of Medicine, for their valuable help. The former kindly undertook the revision of the chapter on General Anatomy or Histology; while the latter rendered great assistance in the revision and proof-reading of some of the other portions of the work.

It is hoped that this edition will maintain the reputation which the work has for so many years enjoyed.

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SIDE VIEW OF THE LOWER JAW AT DIFFERENT PERIODS OF LIFE.

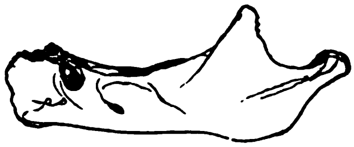

FIG. 67.—At birth.

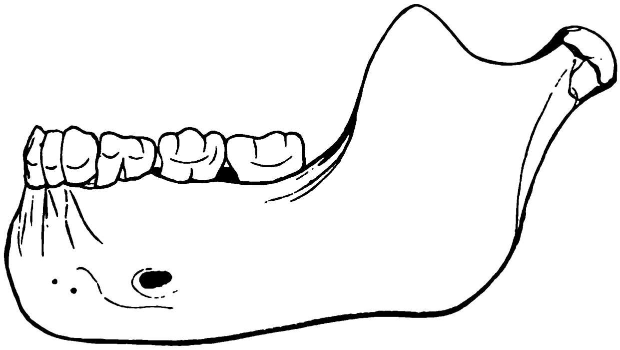

FIG. 68.—At seven years.

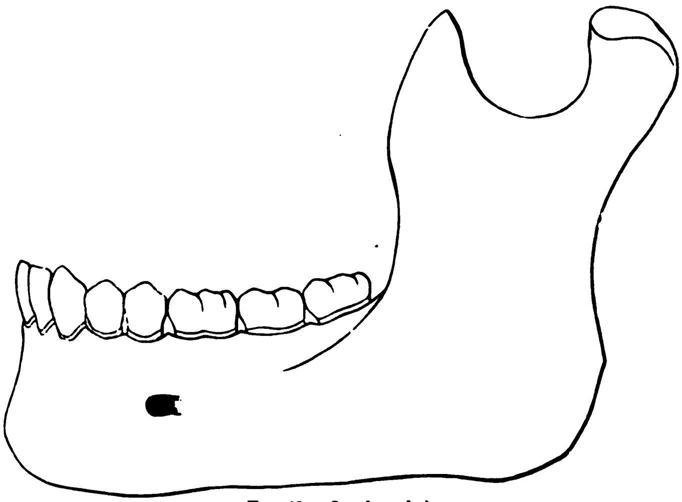

FIG. 69.—In the adult.

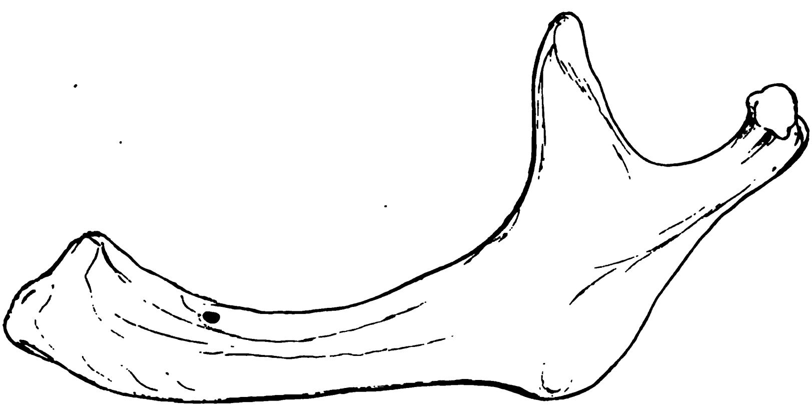

FIG. 70.—In old age.

The sesamoid bones of the joints in the upper extremity, are two on the palmar surface of the metacarpo-phalangeal joint in the thumb, developed in the tendons of the Flexor brevis pollicis; occasionally one or two opposite the metacarpo-phalangeal articulations of the fore and little fingers; and, still more rarely, one opposite the same joints of the third and fourth fingers. In the lower extremity. the patella, which is developed in the tendon of the Quadriceps extensor; two small sesamoid bones, found in the tendons of the Flexor brevis hallucis, opposite the metatarso-phalangeal joint of the great toe; and occasionally one in the metatarso-phalangeal joint of the second toe, the little toe, and, still more rarely, the third and fourth toes.

Those found in the tendons which glide over certain bones occupy the following situations: one sometimes found in the tendon of the Biceps cubiti, opposite the tuberosity of the radius: one in the tendon of the Peroneus longus, where it glides through the groove in the cuboid bone; one appears late in life in the tendon of the Tibialis anticus, opposite the smooth facet of the internal cuneiform bone; one is found in the tendon of the Tibialis posticus, opposite the inner side of the head of the astragalus; one in the outer head of the Gastrocnemius, behind the outer condyle of the femur; and one in the conjoined tendon of the Psoas and Iliacus, where it glides over the os pubis. Sesamoid bones are found occasionally in the tendon of the Gluteus maximus, as it passes over the great trochanter, and in the tendons which wind round the inner and outer malleoli.

In oblique fracture of the *shaft of the tibia* (Fig. 270), if the fracture has taken place obliquely from above, downward and forward, the fragments ride over one another, the lower fragments being drawn backward and upward by the powerful action of the muscles of the calf; the pointed extremity of the upper fragment projects forward immediately beneath the integument, often protruding through it and rendering the fracture a compound one. If the direction of the fracture is the reverse of that shown in the figure, the pointed extremity of the lower fragment projects forward, riding upon the lower end of the upper one. By bending the knee, which relaxes the opposing muscles, and making extension from the ankle and counter-extension at the knee, the fragments may be brought into apposition. It is often necessary, however, in compound fracture, to remove a portion of the projecting bone with the saw before complete adaptation can be effected.

Fracture of the *fibula with dislocation of the foot outward* (Fig. 271), commonly known as "Pott's fracture," is one of the most frequent injuries of the ankle-joint. The fibula is fractured about three inches above the ankle; in addition to this the internal malleolus is broken off, or the deltoid ligament torn through, and the end of the tibia displaced from the corresponding surface of the astragalus. The foot is markedly everted, and the sharp edge of the upper end of the fractured malleolus presses strongly against the skin; at the same time, the heel is drawn up by the muscles of the calf. This injury can generally be reduced by flexing the leg at right angles with the thigh, which relaxes all the opposing muscles, and by making extension from the ankle and counter-extension at the knee.

Plan of the Relations of the Internal Iliac Artery.

In front.
Peritoneum.
Ureter.

Outer side.
Psoas magnus.

Internal Iliac.

Behind.
Internal iliac vein.
Lumbo-sacral cord.
Pyriformis muscle.

In the fœtus the internal iliac artery (*hypogastric*) is twice as large as the external iliac, and appears to be the continuation of the common iliac. Instead of dipping into the pelvis, it passes forward to the bladder, and ascends along the sides of that viscus to its summit, to which it gives branches; it then passes upward along the back part of the anterior wall of the abdomen to the umbilicus, converging toward its fellow of the opposite side. Having passed through the umbilical opening, the two arteries twine round the umbilical vein, forming with it the umbilical cord, and ultimately ramify in the placenta. The portion of the vessel within the abdomen is called the *hypogastric artery*, and that external to that cavity, the *umbilical artery*.

At birth, when the placental circulation ceases, the upper portion of the hypogastric artery, extending from the summit of the bladder to the umbilicus, contracts, and ultimately dwindles to a solid fibrous cord; but the lower portion, extending from its origin (in what is now the internal iliac artery) for about an inch and a half to the wall of the bladder, and thence to the summit of that organ, is not totally impervious, though it becomes considerably reduced in size, and serves to convey blood to the bladder under the name of the *superior vesical artery*.

Peculiarities as regards Length.—In two-thirds of a large number of cases the length of the internal iliac varied between an inch and an inch and a half; in the remaining third it was more frequently longer than shorter, the maximum length being three inches. the minimum half an inch.

The lengths of the common and internal iliac arteries bear an inverse proportion to each other, the internal iliac artery being long when the common iliac is short, and *vice versâ*.

As regards its Place of Division.—The place of division of the internal iliac varies between the upper margin of the sacrum and the upper border of the sacro-sciatic foramen.

The arteries of the two sides in a series of cases often differed in length, but neither seemed constantly to exceed the other.

Surgical Anatomy.—The application of a ligature to the internal iliac artery may be required in cases of aneurism or hæmorrhage affecting one of its branches. The vessel may be secured by making an incision through the abdominal parietes in the iliac region in a direction and to an extent similar to that for securing the common iliac; the transversalis fascia having been cautiously divided, and the peritoneum pushed inward from the iliac fossa toward the pelvis, the finger may feel the pulsation of the external iliac at the bottom of the wound, and by tracing this vessel upward the internal iliac is arrived at, opposite the sacro-iliac articulation. It should be remembered that the vein lies behind and on the right side, a little external to the artery, and in close contact with it; the ureter and peritoneum, which lie in front, must also be avoided. The degree of facility in applying a ligature to this vessel will mainly depend upon its length. It has been seen that in the great majority of the cases examined the artery was short, varying from an inch to an inch and a half; in these cases the artery is deeply seated in the pelvis; when, on the contrary, the vessel is longer, it is found partly above that cavity. If the artery is very short, as occasionally happens, it would be preferable to apply a ligature to the common iliac or upon the external and internal iliacs at their origin.

Probably a better method of tying the internal iliac artery is by an abdominal section in the median line and reaching the vessel through the peritoneal cavity. This plan has been advocated by Dennis of New York on the following grounds: (1) It no way increases the danger of the operation; (2) it prevents a series of accidents which have occurred during ligature of the artery by the older methods; (3) it enables the surgeon to ascertain the exact extent of disease

in the main arterial trunk, and select his spot for the application of the ligature; and (4) it occupies much less time.

Collateral Circulation.—In Professor Owen's dissection of a case in which the internal iliac artery had been tied by Stevens ten years before death for aneurism of the sciatic artery, the internal iliac was found impervious for about an inch above the point where the ligature had been applied, but the obliteration did not extend to the origin of the external iliac, as the ilio-lumbar artery arose just above this point. Below the point of obliteration the artery resumed its natural diameter, and continued so for half an inch, the obturator, lateral sacral, and gluteal arising in succession from the latter portion. The obturator artery was entirely obliterated. The lateral sacral artery was as large as a crow's quill, and had a very free anastomosis with the artery of the opposite side and with the middle sacral artery. The sciatic artery was entirely obliterated as far as its point of connection with the aneurismal tumor, but on the distal side of the sac it was continued down along the back of the thigh nearly as large in size as the femoral, being pervious about an inch below the sac by receiving an anastomosing vessel from the profunda.[1] The circulation was carried on by the anastomoses of the uterine and ovarian arteries; of the opposite vesical arteries; of the hæmorrhoidal branches of the internal iliac with those from the inferior mesenteric; of the obturator artery, by means of its pubic branch, with the vessel of the opposite side and with the epigastric and internal circumflex; of the circumflex and perforating branches of the profunda femoris with the sciatic; of the gluteal with the posterior branches of the sacral arteries; of the ilio-lumbar with the last lumbar; of the lateral sacral with the middle sacral; and of the circumflex iliac with the ilio-lumbar and gluteal.

BRANCHES OF THE INTERNAL ILIAC.

From the Anterior Trunk.	*From the Posterior Trunk.*
Superior Vesical.	Ilio-lumbar.
Middle Vesical.	Lateral Sacral.
Inferior Vesical.	Gluteal.
Middle Hæmorrhoidal.	
Obturator.	
Internal Pudic.	
Sciatic.	
In female { Uterine.	
In female { Vaginal.	

The **superior vesical** is that part of the fœtal hypogastric artery which remains pervious after birth. It extends to the side of the bladder, distributing numerous branches to the apex and body of the organ. From one of these a slender vessel is derived which accompanies the vas deferens in its course to the testis, where it anastomoses with the spermatic artery. This is the *artery of the vas deferens.* Other branches supply the ureter.

The **middle vesical,** usually a branch of the superior, is distributed to the base of the bladder and under surface of the vesiculæ seminales.

The **inferior vesical** arises from the anterior division of the internal iliac, frequently in common with the middle hæmorrhoidal, and is distributed to the base of the bladder, the prostate gland, and vesiculæ seminales. The branches distributed to the prostate communicate with the corresponding vessel of the opposite side.

The **middle hæmorrhoidal artery** usually arises together with the preceding vessel. It supplies the anus and parts outside the rectum, anastomosing with the other hæmorrhoidal arteries.

The **uterine artery** (Fig. 313) passes inward from the anterior trunk of the internal iliac to the neck of the uterus. Ascending in a tortuous course on the side of this viscus, between the layers of the broad ligament, it distributes branches to its substance, anastomosing, near its termination, with a branch from the ovarian artery. It gives off branches to the cervix uteri (*cervical*), and branches which descend on the vagina, and, joining with branches from the vaginal arteries, form a median longitudinal vessel both in front and behind; these descend on the anterior and posterior surfaces of the vagina, and are named the *azygos arteries of the vagina.*

[1] *Medico-Chirurgical Trans.*, vol. xvi.

The **vaginal artery** is analogous to the inferior vesical in the male; it descends upon the vagina, supplying its mucous membrane, and sending branches to the neck of the bladder and contiguous part of the rectum. It assists in forming the azygos arteries of the vagina.

FIG. 313.—The arteries of the internal organs of generation of the female, seen from behind. (After Hyrtl.)

The **Obturator Artery** usually arises from the anterior trunk of the internal iliac; frequently from the posterior. It passes forward, below the brim of the pelvis, to the upper part of the obturator foramen, and, escaping from the pelvic cavity through a short canal formed by a groove on the under surface of the ascending ramus of the os pubis and the arched border of the obturator membrane, it divides into an internal and external branch. In the pelvic cavity this vessel lies upon the pelvic fascia, beneath the peritoneum, and a little below the obturator nerve.

Branches.—*Within the pelvis*, the obturator artery gives off an *iliac branch* to the iliac fossa, which supplies the bone and the Iliacus muscle, and anastomoses with the ilio-lumbar artery; a *vesical branch*, which runs backward to supply the bladder; and a *pubic branch*, which is given off from the vessel just before it leaves the pelvic cavity. This branch ascends upon the back of the os pubis, communicating with offsets from the deep epigastric artery and with the corresponding vessel of the opposite side. It is placed on the inner side of the femoral ring. *External to the pelvis*, the obturator artery divides into an *internal* and an *external branch*, which are deeply situated beneath the Obturator externus muscle.

The **internal branch** curves downward along the inner margin of the obturator foramen, lying beneath the Obturator externus muscle; it distributes branches to the Obturator externus, Pectineus, Adductors, and Gracilis, and anastomoses with the external branch and with the internal circumflex artery.

The **external branch** curves round the outer margin of the foramen, also lying beneath the Obturator externus muscle, to the space between the Gemellus inferior and Quadratus femoris, where it divides into two branches: one, the smaller, courses inward around the lower margin of the foramen and anastomoses with the internal branch and with the internal circumflex; the other inclines outward in the groove

below the acetabulum, and supplies the muscles attached to the tuberosity of the ischium and anastomoses with the sciatic artery. It sends a branch to the hip-joint through the cotyloid notch, which ramifies on the round ligament as far as the head of the femur.

Peculiarities.—In two out of every three cases the obturator arises from the internal iliac; in one case in three and a half from the epigastric; and in about one in seventy-two cases by two roots from both vessels. It arises in about the same proportion from the external iliac artery. The origin of the obturator from the epigastric is not commonly found on both sides of the same body.

When the obturator artery arises at the front of the pelvis from the epigastric, it descends almost vertically to the upper part of the obturator foramen. The artery in this course usually lies in contact with the external iliac vein and on the outer side of the femoral ring (Fig. 314, A); in such cases it would not be endangered in the operation for femoral hernia. Occasionally, however, it curves inward along the free margin of Gimbernat's ligament (Fig. 314, B), and

A B

FIG. 314.—Variations in origin and course of obturator artery.

under such circumstances would almost completely encircle the neck of a hernial sac (supposing a hernia to exist in such a case), and would be in great danger of being wounded if an operation was performed.

The **internal pudic** is the smaller of the two terminal branches of the anterior trunk of the internal iliac, and supplies the external organs of generation. Though the course of the artery is the same in the two sexes, the vessel is much smaller in the female than in the male, and the distribution of its branches somewhat different. The description of its arrangement in the male will first be given, and subsequently the differences which it presents in the female will be mentioned.

The **Internal Pudic Artery in the Male** passes downward and outward to the lower border of the great sacro-sciatic foramen, and emerges from the pelvis between the Pyriformis and Coccygeus muscles: it then crosses the spine of the ischium and re-enters the pelvis through the lesser sacro-sciatic foramen. The artery now crosses the Obturator internus muscle along the outer wall of the ischio-rectal fossa, being situated about an inch and a half above the lower margin of the ischial tuberosity. It is here contained in a sheath of the obturator fascia, and gradually approaches the margin of the ramus of the ischium, along which it passes forward and upward, pierces the base of the superficial layer of the triangular ligament of the urethra, and runs forward along the inner margin of the ramus of the os pubis, and divides into its two terminal branches, the *dorsal artery of the penis* and the *artery of the corpus cavernosum.*

Relations.—In the first part of its course, within the pelvis, it lies in front of the Pyriformis muscle and sacral plexus of nerves, and the sciatic artery, and on the outer side of the rectum (on the left side). As it crosses the spine of the ischium it is covered by the Gluteus maximus and overlapped by the great sacro-sciatic ligament. Here the obturator nerve lies to the inner side and the nerve to the Obturator internus to the outer side of the vessel. In the pelvis it lies on the outer side of the ischio-rectal fossa, upon the surface of the Obturator internus muscle, contained in a fibrous canal (canal of Alcock) formed by the splitting of the obturator fascia. It is accompanied by the pudic veins and the pudic nerve.

Peculiarities.—The internal pudic is sometimes smaller than usual, or fails to give off one or two of its usual branches; in such cases the deficiency is supplied by branches derived from an additional vessel, the *accessory pudic*, which generally arises from the internal pudic artery before its exit from the great sacro-sciatic foramen. It passes forward along the lower part of the bladder and across the side of the prostate gland to the root of the penis, where it perforates the triangular ligament and gives off the branches usually derived from the pudic artery. The deficiency most frequently met with is that in which the internal pudic ends as the artery of the bulb, the artery of the corpus cavernosum and arteria dorsalis penis being derived from the accessory pudic. Or the pudic may terminate as the superficial perineal, the artery of the bulb being derived, with the other two branches, from the accessory vessel. Occasionally the accessory pudic artery is derived from one of the other branches of the internal iliac, most frequently the inferior vesical or the obturator.

Surgical Anatomy.—The relation of the accessory pudic to the prostate gland and urethra is of the greatest interest in a surgical point of view, as this vessel is in danger of being wounded in the lateral operation of lithotomy. The student should also study the position of the internal pudic artery and its branches, when running a normal course with regard to the same operation. The superficial and the transverse perineal arteries are, of necessity, divided in this operation, but the hemorrhage from these vessels is seldom excessive; should a ligature be required, it can readily be applied on account of their superficial position. The artery of the bulb may be divided if the incision be carried too far forward, and injury of this vessel may be attended with serious or even fatal consequences. The main trunk of the internal pudic artery may be wounded if the incision be carried too far outward; but, being bound down by the strong obturator fascia and under cover of the ramus of the ischium, the accident is not very likely to occur unless the vessel runs an anomalous course.

Perineal

FIG. 315.—The internal pudic artery and its branches in the male. (Gegenbaur.)

Branches.—The branches of the internal pudic artery are—

Muscular.	Transverse Perineal.
Inferior Hæmorrhoidal.	Artery of the Bulb.
Superficial Perineal.	Artery of the Corpus Cavernosum
Dorsal Artery of the Penis.	

The **muscular branches** consist of two sets—one given off in the pelvis, the other as the vessel crosses the ischial spine. The former are several small offsets which supply the Levator ani, the Obturator internus, the Pyriformis, and the

Coccygeus muscles. The branches given off outside the pelvis are distributed to the adjacent part of the Gluteus maximus and External rotator muscles. They anastomose with branches of the sciatic artery.

The **inferior hæmorrhoidal** are two or three small arteries which arise from the internal pudic as it passes above the tuberosity of the ischium. Crossing the ischiorectal fossa, they are distributed to the muscles and integument of the anal region.

The **superficial perineal artery** supplies the scrotum and muscles and integument of the perinæum. It arises from the internal pudic in front of the preceding branches, and turns upward, crossing either over or under the Transversus perinæi muscle, and runs forward, parallel to the pubic arch, in the interspace between the Accelerator urinæ and Erector penis muscles, both of which it supplies, and is finally distributed to the skin and dartos of the scrotum. In its passage through the perinæum it lies beneath the superficial perineal fascia.

The **transverse perineal** is a small branch which arises either from the internal pudic or from the superficial perineal artery as it crosses the Transversus perinæi muscle. It runs transversely inward along the cutaneous surface of the Transversus perinæi muscle, which it supplies, as well as the structures between the anus and bulb of the urethra, and anastomoses with the one of the opposite side.

The **artery of the bulb** is a large but very short vessel which arises from the internal pudic between the two layers of the triangular ligament, and, passing nearly transversely inward, between the fibres of the Compressor urethræ muscle, it pierces the bulb of the urethra, in which it ramifies. It gives off a small branch which descends to supply Cowper's gland.

Surgical Anatomy.—This artery is of considerable importance in a surgical point of view, as it is in danger of being wounded in the lateral operation of lithotomy—an accident usually attended in the adult with alarming hemorrhage. The vessel is sometimes very small, occasionally wanting, or even double. It sometimes arises from the internal pudic earlier than usual, and crosses the perinæum to reach the back part of the bulb. In such a case the vessel could hardly fail to be wounded in the performance of the lateral operation of lithotomy. If, on the contrary, it should arise from an accessory pudic, it lies more forward than usual and is out of danger in the operation.

The **artery of the corpus cavernosum**, one of the terminal branches of the internal pudic, arises from that vessel while it is situated between the two layers of the triangular ligament; it pierces the superficial layer, and, entering the crus penis obliquely, it runs forward in the centre of the corpus cavernosum, to which its branches are distributed.

The **dorsal artery of the penis** ascends between the crus and pubic symphysis, and, piercing the triangular ligament, passes between the two layers of the suspensory ligament of the penis, and runs forward on the dorsum of the penis to the glans, where it divides into two branches, which supply the glans and prepuce. On the dorsum of the penis it lies immediately beneath the integument, parallel with the dorsal vein and the corresponding artery of the opposite side. It supplies the integument and fibrous sheath of the corpus cavernosum, sending branches through the sheath to anastomose with the preceding vessel.

The **Internal Pudic Artery in the Female** is smaller than in the male. Its origin and course are similar, and there is considerable analogy in the distribution of its branches. The superficial perineal artery supplies the labia pudendi; the artery of the bulb supplies the bulbi vestibuli and the erectile tissue of the vagina; the artery of the corpus cavernosum supplies the cavernous body of the clitoris; and the arteria dorsalis clitoridis supplies the dorsum of that organ, and terminates in the glans and in the membranous fold corresponding to the prepuce of the male.

The **Sciatic Artery** (Fig. 316), the larger of the two terminal branches of the anterior trunk of the internal iliac, is distributed to the muscles at the back of the pelvis. It passes down to the lower part of the great sacro-sciatic foramen behind the internal pudic artery, resting on the sacral plexus of nerves and Pyriformis

muscle, and escapes from the pelvis through this foramen between the Pyriformis and Coccygeus. It then descends in the interval between the trochanter major and tuberosity of the ischium, accompanied by the sciatic nerves, and covered by the Gluteus maximus, and is continued down the back of the thigh supplying the skin, and anastomosing with branches of the perforating arteries.

Within the pelvis it distributes branches to the Pyriformis, Coccygeus, and Levator ani muscles; some hæmorrhoidal branches, which supply the rectum, and occasionally take the place of the middle hæmorrhoidal artery; and vesical branches to the base and neck of the bladder, vesiculæ seminales, and prostate gland. *External to the pelvis* it gives off the following branches:

- Coccygeal.
- Inferior Gluteal.
- Comes Nervi Ischiadici.
- Muscular.
- Anastomotic.
- Articular.

The **coccygeal branch** runs inward, pierces the great sacrosciatic ligament, and supplies the Gluteus maximus, the integument, and other structures on the back of the coccyx.

The **inferior gluteal branches**, three or four in number, supply the Gluteus maximus muscle, anastomosing with the gluteal artery in the substance of the muscle.

The **comes nervi ischiadici** is a long, slender vessel which accompanies the great sciatic nerve for a short distance; it then penetrates it and runs in its substance to the lower part of the thigh.

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FIG. 316.—The arteries of the gluteal and posterior femoral regions.

The **muscular branches** supply the Gluteus maximus, anastomosing with the gluteal artery in the substance of the muscle: the external rotators, anastomosing with the internal pudic artery; and the muscles attached to the tuberosity of the ischium, anastomosing with the external branch of the obturator and the internal circum… …es.

…otic artery is directed downward across the external rotators, and …g the so-called *crucial anastomosis* by anastomosing with the …ing and the internal and external circumflex.

The **articular branch**, generally derived from the anastomotic, is distributed to the capsule of the hip-joint.

The **Ilio-lumbar Artery**, given off from the posterior trunk of the internal iliac, turns upward and outward between the obturator nerve and lumbo-sacral cord, to the inner margin of the Psoas muscle, behind which it divides into a lumbar and an iliac branch.

The **lumbar branch** supplies the Psoas and Quadratus lumborum muscles, anastomosing with the last lumbar artery, and sends a small spinal branch through the intervertebral foramen, between the last lumbar vertebra and the sacrum, into the spinal canal, to supply the cauda equina.

The **iliac branch** descends to supply the Iliacus muscle; some offsets, running between the muscle and the bone, anastomose with the iliac branch of the obturator; one of these enters an oblique canal to supply the diploë, whilst others run along the crest of the ilium, distributing branches to the Gluteal and Abdominal muscles, and anastomose in their course with the gluteal, circumflex iliac, and external circumflex arteries.

The **Lateral Sacral Arteries** (Fig. 312) are usually two in number on each side, superior and inferior.

The **superior**, which is of large size, passes inward, and, after anastomosing with branches from the middle sacral, enters the first or second anterior sacral foramen, is distributed to the contents of the sacral canal, and, escaping by the corresponding posterior sacral foramen, supplies the skin and muscles on the dorsum of the sacrum, anastomosing with the gluteal.

The **inferior** passes obliquely across the front of the Pyriformis muscle and sacral nerves to the inner side of the anterior sacral foramina, descends on the front of the sacrum, and anastomoses over the coccyx with the sacra media and opposite lateral sacral arteries. In its course it gives off branches which enter the anterior sacral foramina; these, after supplying the contents of the sacral canal, escape by the posterior sacral foramina, and are distributed to the muscles and skin on the dorsal surface of the sacrum, anastomosing with the gluteal.

The **Gluteal Artery** is the largest branch of the internal iliac, and appears to be the continuation of the posterior division of that vessel. It is a short, thick trunk, which passes out of the pelvis above the upper border of the Pyriformis muscle, and immediately divides into a *superficial* and *deep branch*. Within the pelvis it gives off a few muscular branches to the Iliacus, Pyriformis, and Obturator internus, and, just previous to quitting that cavity, a nutrient artery, which enters the ilium.

The **superficial branch** passes beneath the Gluteus maximus and divides into numerous branches, some of which supply that muscle, whilst others perforate its tendinous origin, and supply the integument covering the posterior surface of the sacrum, anastomosing with the posterior branches of the sacral arteries.

The **deep branch** runs between the Gluteus medius and minimus, and subdivides into two. Of these, the superior division, continuing the original course of the vessel, passes along the upper border of the Gluteus minimus to the anterior superior spine of the ilium, anastomosing with the circumflex iliac and ascending branches of the external circumflex artery. The inferior division crosses the Gluteus minimus obliquely to the trochanter major, distributing branches to the Glutei muscles, and inosculates with the external circumflex artery. Some branches pierce the Gluteus minimus to supply the hip-joint.

Surface Marking.—The position of the three main branches of the internal iliac, the sciatic, internal pudic, and gluteal, which may occasionally be the object of surgical interference, is indicated on the surface in the following way: A line is to be drawn from the posterior superior iliac spine to the posterior superior angle of the great trochanter, with the limb slightly flexed and rotated inward: the point of emergence of the *gluteal artery* from the upper part of the sciatic notch will correspond with the junction of the upper with the middle third of this line. A second line is to be drawn from the same point to the outer part of the tuberosity of the ischium: the junction of the lower with the middle third marks the point of emergence of the *sciatic* and *pudic arteries* from the great sciatic notch.

Surgical Anatomy.—Any of these three vessels may require ligating for a wound or for aneurism, which is generally traumatic. The *gluteal* artery is ligated by turning the patient two-thirds over on his face and making an incision from the posterior superior spine of the ilium to the upper and posterior angle of the great trochanter. This must expose the Gluteus maximus muscle, and its fibres are to be separated through the whole thickness of the muscle and pulled apart with retractors. The contiguous margins of the Gluteus medius and Pyriformis are now to be separated from each other, and the artery will be exposed emerging from the sciatic notch. In ligation of the *sciatic* artery, the incision should be made parallel with that for ligation of the gluteal, but one inch and a half lower down. After the fibres of the Gluteus maximus have been separated, the vessel is to be sought for at the lower border of the Pyriformis; the great sciatic nerve, which lies just above it, forming the chief guide to the artery.

The External Iliac Artery (Fig. 312).

The **external iliac artery** is larger in the adult than the internal iliac, and passes obliquely downward and outward along the inner border of the Psoas muscle, from the bifurcation of the common iliac to Poupart's ligament, where it enters the thigh and becomes the femoral artery.

Relations.—*In front*, with the peritoneum, subperitoneal areolar tissue, the termination of the ileum on the right side, and the sigmoid flexure on the left, and a thin layer of fascia derived from the iliac fascia, which surrounds the artery and vein. At its origin it is occasionally crossed by the ureter. The spermatic vessels descend for some distance upon it near its termination, and it is crossed in this situation by the genital branch of the genito-crural nerve and the deep circumflex iliac vein: the vas deferens curves down along its inner side. *Behind*, it is in relation with the external iliac vein, which, at Poupart's ligament, lies at its inner side; on the left side the vein is altogether internal to the artery. *Externally*, it rests against the Psoas muscle, from which it is separated by the iliac fascia. The artery rests upon this muscle, near Poupart's ligament. Numerous lymphatic vessels and glands are found lying on the front and inner side of the vessel.

Plan of the Relations of the External Iliac Artery.

In front.

Peritoneum, intestines, and fascia.

Near Poupart's Ligament. { Lymphatic vessels and glands. Spermatic vessels. Genito-crural nerve (genital branch). Deep circumflex iliac vein.

Outer side.
Psoas magnus.
Iliac fascia.

External Iliac.

Inner side.
External iliac vein and vas deferens near Poupart's ligament.

Behind.
External iliac vein.
Psoas magnus.

Surface Marking.—The surface line indicating the course of the external iliac artery has been already given (see page 560).

Surgical Anatomy.—The application of a ligature to the external iliac may be required in cases of aneurism of the femoral artery or for a wound of the artery. This vessel may be secured in any part of its course, excepting near its upper end, which is to be avoided on account of the proximity of the great stream of blood in the internal iliac, and near its lower end, which should also be avoided, on account of the proximity of the deep epigastric and circumflex iliac vessels. The patient having been placed in the supine position, an incision should be made, commencing below at a point about three-quarters of an inch above Poupart's ligament, and a little external to its middle, and running upward and outward, parallel to Poupart's ligament, to a point one inch internal and one inch above the anterior superior spine of the ilium. When the artery is deeply seated, more room will be required, and may be obtained by curving the incision from the point last named inward toward the umbilicus for a short distance. Another mode of ligating the vessel is the plan advocated by Sir Astley Cooper, by making an incision close to Poupart's ligament from about half an inch outside of the external abdominal ring to one inch internal to the anterior superior spine of the ilium. This incision, being

made in the course of the fibres of the aponeurosis of the external oblique, is less likely to be followed by a ventral hernia, but there is danger of wounding the epigastric artery, and only the lower end of the vessel can be ligated. Abernethy, who first tied this artery, made his incision in the course of the vessel. The abdominal muscles and transversalis fascia having been cautiously divided, the peritoneum should be separated from the iliac fossa and raised toward the pelvis; and on introducing the finger to the bottom of the wound, the artery may be felt pulsating along the inner border of the Psoas muscle. The external iliac vein is generally found on the inner side of the artery, and must be cautiously separated from it by the finger-nail or handle of the knife, and the aneurism needle should be introduced on the inner side, between the artery and the vein.

Ligation of the external iliac artery has recently been performed by a transperitoneal method. An incision four inches in length is made in the semilunar line, commencing about an inch below the umbilicus and carried through the abdominal wall into the peritoneal cavity. The intestines are then pushed upward and held out of the way by a broad abdominal retractor, and an incision made through the peritoneum at the margin of the pelvis in the course of the artery, and the vessel secured in any part of its course which may seem desirable to the operator. The advantages of this operation appear to be that if it is found necessary, the common iliac artery can be ligated instead of the external iliac without extension or modification of the incision; and secondly, that the vessel can be ligated without in any way interfering with the coverings of the sac. Possibly a disadvantage may exist in the greater risk of hernia after this method.

Collateral Circulation.—The principal anastomoses in carrying on the collateral circulation, after the application of a ligature to the external iliac, are—the ilio-lumbar with the circumflex iliac; the gluteal with the external circumflex; the obturator with the internal circumflex; the sciatic with the superior perforating and circumflex branches of the profunda artery; and the internal pudic with the external pudic. When the obturator arises from the epigastric, it is supplied with blood by branches, either from the internal iliac, the lateral sacral, or the internal pudic. The epigastric receives its supply from the internal mammary and inferior intercostal arteries, and from the internal iliac by the anastomoses of its branches with the obturator.

In the dissection of a limb eighteen years after the successful ligature of the external iliac artery by Sir A. Cooper, which is to be found in *Guy's Hospital Reports*, vol. i. p. 50, the anastomosing branches are described in three sets: *An anterior set.*—1, a very large branch from the ilio-lumbar artery to the circumflex iliac; 2, another branch from the ilio-lumbar, joined by one from the obturator, and breaking up into numerous tortuous branches to anastomose with the external circumflex; 3, two other branches from the obturator, which passed over the brim of the pelvis, communicated with the epigastric, and then broke up into a plexus to anastomose with the internal circumflex. *An internal set.*—Branches given off from the obturator, after quitting the pelvis, which ramified among the adductor muscles on the inner side of the hip-joint, and joined most freely with branches of the internal circumflex. *A posterior set.*—1, three large branches from the gluteal to the external circumflex; 2, several branches from the sciatic around the great sciatic notch to the internal and external circumflex, and the perforating branches of the profunda.

Branches.—Besides several small branches to the Psoas muscle and the neighboring lymphatic glands, the external iliac gives off two branches of considerable size—the

Deep Epigastric and Deep Circumflex Iliac.

The **Deep Epigastric Artery** arises from the external iliac a few lines above Poupart's ligament. It at first descends to reach this ligament, and then ascends obliquely along the inner margin of the internal abdominal ring, lying between the transversalis fascia and peritoneum, and, continuing its course upward, it pierces the transversalis fascia, and, passing over the semilunar fold of Douglas, enters the sheath of the Rectus muscle. It then ascends on the posterior surface of the muscle, and finally divides into numerous branches, which anastomose, above the umbilicus, with the superior epigastric branch of the internal mammary and with the inferior intercostal arteries (Fig. 301). The deep epigastric artery bears a very important relation to the internal abdominal ring as it passes obliquely upward and inward from its origin from the external iliac. In this part of its course it lies along the lower and inner margin of the ring and beneath the commencement of the spermatic cord. As it passes to the inner side of the internal abdominal ring it is crossed by the vas deferens in the male and the round ligament in the female.

Branches.—The branches of this vessel are the following: The *cremasteric*, which accompanies the spermatic cord, and supplies the Cremaster muscle and

The **Coronary Sinus** is that portion of the anterior or great cardiac vein which is situated in the posterior part of the left auriculo-ventricular groove. It is about an inch in length, presents a considerable dilatation, and is covered by the muscular fibres of the left auricle. It receives the veins enumerated above, and an *oblique vein* from the back part of the left auricle, the remnant of the obliterated left Cuvierian duct of the fœtus, described by Mr. Marshall. The great coronary sinus terminates in the right auricle, between the inferior vena cava and the auriculo-ventricular aperture, its orifice being guarded by a semilunar fold of the lining membrane of the heart, the *Thebesian valve*. All the veins joining this vessel, excepting the oblique vein above mentioned, are provided with valves.

The **Venæ Thebesii** (*venæ cordis minimæ*) are numerous minute veins, which return the blood directly from the muscular substance, without entering the venous current. They open by minute orifices (*foramina Thebesii*) on the inner surface of the right auricle.

the *tegmental* portion, as most of its constituents are continued into the tegmentum of the crus cerebri.

The anterior or ventral part consists of three layers of fibres: 1. superficial transverse fibres; 2. longitudinal fibres; 3. deep transverse fibres. These three layers are not, however, completely differentiated from each other, for some transverse fibres may be seen between the bundles of the longitudinal fibres (Fig. 362).

1. The *superficial transverse fibres*, consisting of a rather thick layer on the ventral surface of the pons, cross the middle line, and proceeding laterally are collected into a large rounded bundle of fibres on each side. This bundle, with the addition of some transverse fibres from the deeper part of the pons, forms the *middle peduncle* of the cerebellum of the corresponding side.

2. The *longitudinal fibres* enter the pons below as a single mass, which forms the continuation upward of the fibres of the pyramids of the medulla: as they ascend they become broken up into bundles by some of the transverse fibres, and

FIG. 362.—Superficial dissection of the medulla oblongata and pons. (Ellis.)

are continued into the crusta of the mid-brain. They lie on either side of the middle line, and cause a bulging of the superficial transverse fibres on the ventral surface of the pons, with a longitudinal mesial groove between them. This is the groove, mentioned above, in which the basilar artery is received. As the fibres ascend they are increased in number, being reinforced by others derived from the nerve-cells in the deep transverse strata.

3. The *deep transverse fibres* form a thicker layer than the superficial set, and there is much gray matter between them. The fibres pass from the middle line, where they interlace with those from the opposite side, and, coursing to the lateral borders of the pons, they, for the most part, curve dorsally, and assist the superficial transverse fibres in forming the middle peduncle of the cerebellum. Some of the fibres join the nerve-cells which are situated in the gray matter of this layer, and in addition nerve-fibres derived from others of these cells pass off to join the longitudinal fibres (see above).

The *tegmental* or *dorsal portion* of the pons is chiefly constituted by a continuation upward of the reticular formation and gray matter of the medulla. It is subdivided into lateral halves by a median raphé continuous with that of the medulla, but this does not extend into the ventral half of the pons, being here obliterated by the transverse fibres.

The dorsal portion of the pons, like the ventral, contains both transverse and longitudinal fibres. The transverse fibres are collected into a distinct bundle, which, from its shape, is sometimes termed the *trapezium* or *corpus trapezoides*. It consists of fibres which proceed laterally to become connected with the cells of the accessory auditory nucleus. The longitudinal fibres, which are continuous with those of the medulla, are mostly collected into two bundles on either side. One of these lies between the corpus trapezoides and the formatio reticularis of the pons, and is a continuation upward of the sensory tracts; it is termed the *fillet*. The other bundle is situated more dorsally, near the floor of the fourth ventricle; it is the *posterior longitudinal bundle*, and contains both ascending and descending fibres. Other longitudinal fibres, which are more diffusely distributed, arise from the cells of the gray matter of the pons itself. The greater part of the dorsal portion of the pons is, as stated above, a continuation upward of the formatio reticularis of the medulla, and, like it, presents, on transverse section, viewed under a moderate magnifying power, a reticular appearance. In addition to the gray matter, which presents a number of small reticularly arranged masses, with nerve-cells, there are some important collections of nerve-cells which require mention.

1. The **superior olivary nucleus** is a small isolated collection of gray matter, situated on the dorsal surface of the outer part of the trapezium. In structure it resembles the inferior olivary nucleus of the medulla, presently to be described, and is situated immediately above it. The nerve-fibres derived from its cells pass into the trapezium, and, as stated above, cross the middle line and enter the accessory auditory nucleus of the other side. The other collections of nerve-cells in the formatio reticularis of the pons are nuclei from which some of the cranial nerves arise.

2. **Nuclei of the Fifth Nerve.**—The nuclei of the fifth nerve in the pons are two in number: one for the motor root and the other for the sensory. The *motor* nucleus is situated in the higher portion of the pons, close under the dorsal surface and along the line of the lateral margin of the fourth ventricle. The *sensory* nucleus lies external to the motor one, beneath the superior peduncle of the cerebellum, which forms the lateral boundary of the upper half of the fourth ventricle. Some of the fibres from these nuclei pass to the raphé of the pons, and thence probably to the higher parts of the brain; the rest form the nerve-roots of the motor and sensory parts of the fifth nerve respectively. They pass through the pons to emerge on its ventral surface at its lateral and constricted portion, nearer its superior than its inferior margin. It must be mentioned that the whole of the roots of the fifth nerve are not formed from these nuclei. The sensory root is partly formed by a long tract of fibres, known as the *ascending* root, which can be traced through the pons and medulla to the upper part of the spinal cord. The motor root, in like manner, is partly formed by a long tract of fibres, which passes downward from the gray matter in the floor of the Sylvian aqueduct and which is termed the *descending* root.

3. The **nucleus of the sixth nerve** is situated beneath the floor of the fourth ventricle, on either side of the middle line. It lies close to the root of the facial nerve, immediately to be described, being a little external to and beneath it, and corresponds to the upper half of the fasciculus teres of the floor of the fourth ventricle (Fig. 371). The fibres pass through the substance of the pons, and emerge at the lower margin of this structure, between it and the upper end of the medulla.

4. The **nucleus of the facial nerve** is of elongated form, and is situated deeply in the reticular formation below the floor of the fourth ventricle and dorsal to

nerve and gives off a few filaments to the mucous membrane of the lower part of the larynx.

The recurrent laryngeal, as it winds round the subclavian artery and aorta, gives off several cardiac filaments, which unite with the cardiac branches from the pneumogastric and sympathetic. As it ascends in the neck it gives off œsophageal branches, more numerous on the left than on the right side, which supply the mucous membrane and muscular coat of the œsophagus; tracheal branches to the mucous membrane and muscular fibres of the trachea: and some pharyngeal filaments to the Inferior constrictor of the pharynx.

The **cervical cardiac branches,** two or three in number, arise from the pneumogastric, at the upper and lower part of the neck.

The *superior branches* are small, and communicate with the cardiac branches of the sympathetic. They can be traced to the great or deep cardiac plexus.

The *inferior branches*, one on each side, arise at the lower part of the neck, just above the first rib. On the right side this branch passes in front or by the side of the arteria innominata, and communicates with one of the cardiac nerves proceeding to the great or deep cardiac plexus. On the left side it passes in front of the arch of the aorta and joins the superficial cardiac plexus.

The **thoracic cardiac branches,** on the right side, arise from the trunk of the pneumogastric as it lies by the side of the trachea, and from its recurrent laryngeal branch, but on the left side from the recurrent nerve only; passing inward, they terminate in the deep cardiac plexus.

The **anterior pulmonary branches,** two or three in number, and of small size, are distributed on the anterior aspect of the root of the lungs. They join with filaments from the sympathetic, and form the *anterior pulmonary plexus.*

The **posterior pulmonary branches,** more numerous and larger than the anterior, are distributed on the posterior aspect of the root of the lung: they are joined by filaments from the third and fourth (sometimes also first and second) thoracic ganglia of the sympathetic, and form the *posterior pulmonary plexus.* Branches from both plexuses accompany the ramification of the air-tubes through the substance of the lungs.

The **œsophageal branches** are given off from the pneumogastric both above and below the pulmonary branches. The lower are more numerous and larger than the upper. They form, together with branches from the opposite nerve, the *œsophageal plexus* or *plexus gulæ.* From this plexus branches are distributed to the back of the pericardium.

The **gastric branches** are the terminal filaments of the pneumogastric nerve. The nerve on the right side is distributed to the posterior surface of the stomach, and joins the left side of the cœliac plexus and the splenic plexus. The nerve on the left side is distributed over the anterior surface of the stomach, some filaments passing across the great *cul-de-sac*, and others along the lesser curvature. They unite with branches of the right nerve and with the sympathetic, some filaments passing through the lesser omentum to the hepatic plexus.

Surgical Anatomy.—The laryngeal nerves are of considerable importance in considering some of the morbid conditions of the larynx. When the peripheral terminations of the superior laryngeal nerve are irritated by some foreign body passing over them, reflex spasm of the glottis is the result. When the trunk of this same nerve is pressed upon by, for instance, a goitre or an aneurism of the upper part of the carotid, we have a peculiar dry, brassy cough. When the nerve is paralyzed, we have anæsthesia of the mucous membrane of the larynx, so that foreign bodies can readily enter the cavity, and, in consequence of its supplying the crico-thyroid muscle, the vocal cords cannot be made tense, and the voice is deep and hoarse. Paralysis of the superior laryngeal nerves may be the result of bulbar paralysis, may be a sequel to diphtheria, when both nerves are usually involved, or it may, though less commonly, be caused by the pressure of tumors or aneurisms, when the paralysis is generally unilateral. Irritation of the inferior laryngeal nerves produces spasm of the muscles of the larynx. When both these recurrent nerves are paralyzed, the vocal cords are motionless, in the so-called "cadaveric position"—that is to say, in the position in which they are found in ordinary tranquil respiration—neither closed as in phonation, nor open as in deep inspiratory efforts. When one recurrent nerve is paralyzed, the cord of the same side is motionless, while the opposite one crosses the middle line to accommodate itself to the affected one; hence phonation is present, but the voice

Deep . . .	Internal . .	Communicating.
		Muscular.
		Communicantes hypoglossi.
		Phrenic.
	External . .	Communicating.
		Muscular.

Superficial Branches of the Cervical Plexus.

The **Occipitalis minor** (Fig. 415) arises from the second cervical nerve, sometimes also from the third; it curves round the posterior border of the Sterno-mastoid, and ascends, running parallel to the posterior border of the muscle, to the back part of the side of the head. Near the cranium it perforates the deep fascia, and is continued upward along the side of the head behind the ear, supplying the integument, and communicating with the occipitalis major, the auricularis magnus, and with the posterior auricular branch of the facial.

This nerve gives off an *auricular branch*, which supplies the integument of the upper and back part of the auricle, communicating with the mastoid branch of the auricularis magnus. This branch is occasionally derived from the great occipital nerve. The occipitalis minor varies in size; it is occasionally double.

The **Auricularis Magnus** is the largest of the ascending branches. It arises from the second and third cervical nerves, winds round the posterior border of the Sterno-mastoid, and, after perforating the deep fascia, ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into facial, auricular, and mastoid branches.

The *facial branches* pass across the parotid, and are distributed to the integument of the face over the parotid gland; others penetrate the substance of the gland and communicate with the facial nerve.

The *auricular branches* ascend to supply the integument of the back of the pinna, except at its upper part, communicating with the auricular branches of the facial and pneumogastric nerves. A filament pierces the pinna to reach its outer surface, where it is distributed to the lobule and lower part of the concha.

The *mastoid branch* communicates with the occipitalis minor and the posterior auricular branch of the facial, and is distributed to the integument behind the ear.

The **Superficialis Colli** arises from the second and third cervical nerves, turns round the posterior border of the Sterno-mastoid about its middle, and, passing obliquely forward beneath the external jugular vein to the anterior border of the muscle, perforates the deep cervical fascia, and divides beneath the Platysma into two branches which are distributed to the antero-lateral parts of the neck.

The *ascending branch* gives a filament which accompanies the external jugular vein; it then passes upward to the submaxillary region, and divides into branches, some of which form a plexus with the cervical branches of the facial nerve beneath the Platysma; others pierce that muscle and are distributed to the integument of the upper half of the neck, at its fore part, as high as the chin.

The *descending branch* (occasionally represented by two or more filaments) pierces the Platysma, and is distributed to the integument of the side and front of the neck, as low as the sternum.

The **Descending** or **supraclavicular branches** arise from the third and fourth cervical nerves: emerging beneath the posterior border of the Sterno-mastoid, they descend in the posterior triangle of the neck beneath the Platysma and deep cervical fascia. Near the clavicle they perforate the fascia and Platysma to become cutaneous, and are arranged, according to their position, into three groups.

The *inner* or *suprasternal branches* cross obliquely over the external jugular vein and the clavicular and sternal attachments of the Sterno-mastoid, and supply the integument as far as the median line. They furnish one or two filaments to the sterno-clavicular joint.

a *cul-de-sac ;* its anterior extremity becomes constricted into a narrow straight duct, which joins with the corresponding vas deferens, and forms the ejaculatory duct.

The **ejaculatory ducts,** two in number, one on each side, are formed by the junction of the ducts of the vesiculæ seminales with the vasa deferentia. Each duct is about three-quarters of an inch in length ; it commences at the base of the prostate, and runs forward and downward between its middle and lateral lobes, and along the side of the sinus pocularis, to terminate by a separate slit-like orifice close to or just within the margins of the sinus. The ducts diminish in size and also converge toward their termination.

Structure.—The vesiculæ seminales are composed of three coats : an *external* or *areolar ;* a *middle* or *muscular coat,* which is thinner than in the vas deferens, arranged in two layers, an outer, longitudinal, and inner, circular ; an *internal* or *mucous coat,* which is pale, of a whitish-brown color, and presents a delicate reticular structure, like that seen in the gall-bladder, but the meshes are finer. The epithelium is columnar.

The coats of the ejaculatory ducts are extremely thin. They are : an *outer fibrous layer,* which is almost entirely lost after their entrance into the prostate ; a *layer of muscular fibres,* consisting of an outer thin circular and an inner longitudinal layer ; and the *mucous membrane.*

Vessels and Nerves.—The *arteries* supplying the vesiculæ seminales are derived from the middle and inferior vesical and middle hæmorrhoidal. The *veins* and *lymphatics* accompany the arteries. The *nerves* are derived from the pelvic plexus.

Surgical Anatomy.—The vesiculæ seminales are often the seat of an extension of the disease in cases of tuberculous disease of the testicle, and should always be examined from the rectum before coming to a decision with regard to castration in this affection.

on to the side of the bladder, forming the lateral true ligaments of the organ. Another prolongation invests the vesiculæ seminales, and passes across between the bladder and rectum, being continuous with the same fascia of the opposite side. Another thin prolongation is reflected round the surface of the lower end of the rectum. The Levator ani muscle arises from the point of division of the pelvic fascia, the visceral layer of the fascia descending upon and being intimately adherent to the upper surface of the muscle, while the under surface of the muscle is covered by a thin layer derived from the obturator fascia, called the *ischio-rectal* or *anal fascia.* In the female the vagina perforates the recto-vesical fascia, and receives a prolongation from it.

separated from the blood-corpuscles. In human blood the crystals are elongated prisms (Fig. 601, *A*), and in the majority of animals belong to the rhombic system, though in the squirrel hexagonal plates are met with. Small brown prismatic crystals of *hæmin* (Fig. 601, *B*) may be obtained by mixing dried blood with common salt and boiling with a few drops of glacial acetic acid. A drop of the mixture on a slide will show the characteristic crystals on cooling. *Hæmatoidin* crystals (Fig. 601, *C*) occur sometimes in old blood-clots.

LYMPH AND CHYLE.

Lymph is a transparent, colorless or slightly yellow fluid, which is conveyed by a set of vessels named *lymphatics* into the blood. These vessels arise in nearly all parts of the body as *lymph-capillaries*. They take up the blood-plasma which has exuded from the blood-capillaries into the tissue-spaces where it has nourished the tissue-elements, and return it into the veins close to the heart, there to be mixed with the mass of blood. The greater number of these lymphatics empty themselves into one main duct, the *thoracic duct*, which passes upward along the front of the spine and opens into the large veins on the left side of the root of the neck. The remainder empty themselves into a smaller duct which terminates in the corresponding veins on the right side of the neck.

Lymph, as its name implies, is a watery fluid of sp. gr. about 1.015, closely resembling the blood-plasma, but more dilute and containing only about 5 per cent. of proteids and 1 per cent. of salts and extractives. When examined under the microscope, leucocytes of the lymphocyte class are found floating in the transparent fluid. They are always increased in number after the passage of the lymph through lymphoid tissue, as in lymphatic glands. They are constantly furnishing a fresh supply of colorless corpuscles to the blood.

Chyle is an opaque, milky-white fluid, absorbed by the villi of the small intestine from the food, and carried by a set of vessels similar to the lymphatics, named *lacteals*, to the commencement of the thoracic duct, where it is intermingled with the lymph and poured into the circulation through the same channels. It must be borne in mind that these two sets of vessels, lymphatics and lacteals, though differing in name, are identical in structure, and that the character of the fluid they convey is different only while digestion is going on. At other times the lacteals convey a transparent, nearly colorless lymph.

Chyle exactly resembles lymph in its physical and chemical properties, except that it has, in addition to the other constituents of lymph, a quantity of finely divided fatty particles, the so-called "molecular basis of chyle," to which the milky appearance is due. It contains a little more proteid than lymph, but the chief difference lies in the large quantity of fats, soaps, lecithin, and cholesterin present in the former. Lymph and chyle, containing, as they do, fibrinogen in solution and leucocytes, clot on removal from the body, the coagulum being free from red cells, and presenting a clear or whitish jelly-like appearance.

EPITHELIUM.

All the surfaces of the body—the external surface of the skin, the internal surface of the digestive, respiratory, and genito-urinary tracts, the closed serous cavities, the inner coat of the vessels, and the acini and ducts of all secreting and excreting glands, the ventricles of the brain, and the central canal of the spinal cord—are covered by one or more layers of simple cells, called *epithelium* or *epithelial cells*. These cells are also present in the terminal parts of the organs of special sense, and in some other structures, as the pituitary and thyroid bodies. They serve various purposes, forming in some cases a protective layer, in others acting as agents in secretion and excretion, and again in others being concerned in the elaboration of the organs of special sense. Thus, in the skin, the main purpose served by the epithelium (here called the *epidermis*) is that of protection. As the surface is worn away by the agency of friction or change of

layer, composed of cells joined edge to edge by an interstitial cement-substance, and continuous with the endothelial cells which line the arteries and veins. When stained with nitrate of silver the edges which bound the epithelial cells are brought into view (Fig. 668). These cells are of large size and of an irregular polygonal or lanceolate shape, each containing an oval nucleus which may be brought into view by carmine or hæmatoxylin. Between their edges, at various points of their meeting, roundish dark spots are sometimes seen, which have been described as stomata, though they are closed by intercellular substance. They have been believed to be the situation through which the white corpuscles of the blood, when migrating from the blood-vessels, emerge; but this view, though probable, is not universally accepted.

Kolossow, a Russian observer, describes these cells as having a rather more complex structure. He states that they consist of two parts: of hyaline ground-plates, and of a protoplasmic granular part, in which is imbedded the nucleus, on the outside of the ground-plates. The hyaline internal coat of the capillaries does not form a complete membrane, but consists of "plates" which are inelastic, and, though in contact with each other, are not continuous; when, therefore, the capillaries are subjected to intra-vascular pressure, the plates become separated from each other; the protoplasmic portions of the cells, on the other hand, are united together.

In many situations a delicate sheath or envelope of branched nucleated connective-tissue cells is found around the simple capillary tube, particularly in the larger ones; and in other places, especially in the glands, the capillaries are invested with retiform connective tissue.

In the largest capillaries (which ought, perhaps, to be described rather as the smallest arteries or pre-capillaries) there is, outside the epithelial layer, a muscular layer, consisting of contractile fibre-cells, arranged transversely, as in the tunica media of the larger arteries (Fig. 669).

The **veins**, like the arteries, are composed of three coats—internal, middle, and external; and these coats are, with the necessary modifications, analogous to the coats of the arteries; the internal being the endothelial, the middle the muscular, and the external the connective or areolar (Fig. 670). The main difference be-

Endothelial and subendothelial layers.
Elastic layer.
Middle coat.
Outer coat.

FIG. 670.—Transverse section of part of the wall of one of the posterior tibial veins. (After Schäfer)

tween the veins and the arteries is the comparative weakness of the middle coat of the former, and to this is due the fact that the veins do not stand open when divided, as the arteries do, and that they are passive rather than active organs of the circulation.

In the veins immediately above the capillaries the three coats are hardly to be distinguished. The endothelium is supported on an outer membrane separable into two layers, the outer of which is the thicker, and consists of a delicate, nucleated membrane (adventitia), while the inner is composed of a network of longitudinal elastic fibres (media). In the veins next above these in size (one-fifth of a line, according to Kölliker) a muscular layer and a layer of circular fibres can be traced, forming the middle coat, while the elastic and connective elements of the outer coat become more distinctly perceptible. In the middle-sized veins the typical structure of these vessels becomes clear. The endothelium is of the same character

opaque and deeper colored when viewed by transmitted light than the fibrous part: but when viewed by reflected light it is white. It is composed of rows of polyhedral cells, which contain granules of eleidin and frequently air-bubbles. The fibrous portion of the hair constitutes the chief part of the shaft; its cells are elongated and unite to form flattened fusiform fibres. Between the fibres are found minute spaces which contain either pigment-granules in dark hair or minute air-bubbles in white hair. In addition to this there is also a diffused pigment contained in the fibres. The cells which form the cortex of the hair consist of a single layer which surrounds those of the fibrous part; they are converted into thin, flat scales, having an imbricated arrangement.

Connected with the hair-follicles are minute bundles of involuntary muscular fibres, termed *arrectores pili.* They arise from the superficial layer of the corium, and are inserted into the outer surface of the hair-follicle, below the entrance of the duct of the sebaceous gland. They are placed on the side toward which the hair slopes, and by their action elevate the hair (Fig. 679).[1]

The **sebaceous glands** are small, sacculated, glandular organs, lodged in the substance of the corium. They are found in most parts of the skin, but are especially abundant in the scalp and face: they are also very numerous around the apertures of the anus, nose, mouth, and external ear; but are wanting in the palms of the hands and soles of the feet. Each gland consists of a single duct, more or less capacious, which terminates in a cluster of small secreting pouches or saccules. The sacculi connected with each duct vary, as a rule, in number from two to five, but in some instances may be as many as twenty. They are composed of a transparent, colorless membrane, enclosing a number of epithelial cells. Those of the outer or marginal layer are small and polyhedral, and are continuous with the lining cells of the duct. The remainder of the sac is filled with larger cells, containing fat, except in the centre, where the cells have become broken up, leaving a cavity containing their débris and a mass of fatty matter, which constitutes the sebaceous secretion. The orifices of the ducts open most frequently into the hair-follicles, but occasionally upon the general surface, as in the labia minora and the free margin of the lips. On the nose and face the glands are of large size, distinctly lobulated, and often become much enlarged from the accumulation of pent-up secretion. The largest sebaceous glands are those found in the eyelids—the Meibomian glands.

The **sudoriferous** or **sweat-glands** are the organs by which a large portion of the aqueous and gaseous materials is excreted by the skin. They are found in almost every part of this structure, and are situated in small pits on the under surface of the corium, or, more frequently, in the subcutaneous areolar tissue, surrounded by a quantity of adipose tissue. They are small, lobular, reddish bodies, consisting of a single convoluted tube, from which the efferent duct proceeds upward through the corium and cuticle, becomes somewhat dilated at its extremity, and opens on the surface of the cuticle by an oblique valve-like aperture. The efferent duct, as it passes through the epidermis, presents a spiral arrangement, being twisted like a corkscrew, in those parts where the epidermis is thick; where, however, it is thin, the spiral arrangement does not exist. In the superficial layers of the corium the duct is straight, but in the deeper layers it is convoluted or even twisted. The spiral course of these ducts is especially distinct in the thick cuticle of the palm of the hand and sole of the foot. The size of the glands varies. They are especially large in those regions where the amount of perspiration is great, as in the axillæ, where they form a thin, mammillated layer of a reddish color, which corresponds exactly to the situation of the hair in this region; they are large also in the groin. Their number varies. They are most numerous on the palm of the hand, presenting, according to Krause, 2800 orifices on a square

[1] Arthur Thomson suggests that the contraction of these muscles on follicles which contain weak flat hairs will tend to produce a permanent curve in the follicle, and this curve will be impressed on the hair which is moulded within it, so that the hair, on emerging through the skin, will be curled. Curved hair-follicles are characteristic of the scalp of the Bushman.

But this communication is closed during life, except at the moment of the passage of the ovum out of the ovary into the tube, as is proved by the fact that no interchange of fluids ever takes place between the two cavities in dropsy of the peritoneum or in accumulation of fluid in the Fallopian tubes.[1] The serous membrane is often supported by a firm, fibrous layer, as is the case with the pericardium, and such membranes are sometimes spoken of as "fibro-serous."

The various serous membranes are the peritoneum, lining the cavity of the abdomen; the two pleuræ and the pericardium, covering the lungs and heart respectively; and the tunicæ vaginales, surrounding each testicle in the scrotum.[2] Serous membranes are thin, transparent, glistening structures, lined on their inner surface by a single layer of polygonal or pavement endothelial cells, supported on a matrix of fibrous connective tissue, with networks of fine elastic fibres, in which are contained numerous capillaries and lymphatics. On the surface of the endothelium between the cells numerous apertures or interruptions are to be seen. Some of these are stomata, surrounded by a ring of cubical endothelium (see Fig. 684),

FIG. 684.—Part of peritoneal surface of the central tendon of diaphragm of rabbit, prepared with nitrate of silver. *s.* Stomata. *l.* Lymph-channels. *t.* Tendon-bundles. The stomata are surrounded by germinating epithelial cells. (From *Handbook for the Physiological Laboratory*, Klein.)

and communicating with a lymphatic capillary; others (*pseudostomata*) are mere interruptions in the endothelial layer, and are occupied by processes of the branched connective-tissue corpuscle of the subjacent tissue or by accumulations of the intercellular cement-substance.

The amount of fluid contained in these closed sacs is, in most cases, only sufficient to moisten the surface, but not to furnish any appreciable quantity of fluid. When a small quantity can be collected, it is found to resemble lymph, and like that fluid coagulates spontaneously; but when secreted in large quantities, as in dropsy, it is a more watery fluid, but still contains a considerable amount of proteid which is coagulated on boiling.

[1] The communication between the uterine cavity and the peritoneal sac is not only apparent in the dead subject, but is an anatomical fact, which is established by the continuity of its epithelium with that covering the uterus, Fallopian tubes, and fimbriæ.

[2] The arachnoid membrane, lining the brain and spinal cord, was formerly regarded as a serous membrane, but is now no longer classed with them, as it differs from them in structure, and does not form a shut sac as do the other serous membranes.

tissue. This tissue is usually covered on its external surface by a transparent basement-membrane generally composed of clear flattened cells, placed edge to edge; on this the epithelium rests. It is only in some situations that the basement-membrane can be demonstrated. The corium is an exceedingly vascular membrane, containing a dense network of capillaries, which lie immediately beneath the epithelium, and are derived from small arteries in the submucous tissue.

The fibro-vascular layer of the corium contains, besides the areolar tissue and vessels, unstriped muscle-cells, which form in many situations a definite layer, called the *muscularis mucosæ*. These are situated in the deepest part of the membrane, and are plentifully supplied with nerves. Other nerves pass to the epithelium and terminate between the cells. Lymphatic vessels are found in great abundance, commencing either by cæcal extremities or in networks, and communicating with plexuses in the submucous tissue.

Imbedded in the mucous membrane are found numerous glands, and projecting from it are processes (villi and papillæ) analogous to the papillæ of the skin. These glands and processes, however, exist only at certain parts, and they have been described for the sake of convenience, and with the parts as they occurred.

SECRETING GLANDS.

The **secreting glands** are organs whose cells produce, by the metabolism of their protoplasm, certain substances, called "secretions," of a more or less definite composition; the material for the secretion being primarily selected from the blood. The essential parts, therefore, of a secreting gland are *cells*, which have the power of extracting from the blood certain matters, and in some cases converting them into new chemical compounds; and *blood-vessels*, by which the blood is brought into close relationship with these cells. The general arrangement in all secreting structures—that is to say, not only in secreting glands, but also in secreting membranes—is that the cells are arranged on one surface of an extravascular basement-membrane, which supports them, and a minute plexus of capillary vessels ramifies on the other surface of the membrane. The cells then extract from the blood certain constituents which pass through the membrane into the cells, where they are prepared and elaborated. The basement-membrane does not, however, always exist, and any free surface would appear to answer the same purpose in some cases.

By the various modifications of this secreting surface the different glands are formed. This is generally effected by an invagination of the membrane in different ways, the object being to increase the extent of secreting surface within a given bulk.

In the simplest form a single invagination takes place, constituting a *simple* gland; this may be either in the form of an open tube (Fig. 686, A), or the walls of the tube may be dilated so as to form a saccule (Fig. 686, B). These are named the *simple tubular* or *saccular* glands. Or, instead of a short tube, the invagination may be lengthened to a considerable extent, and then coiled up to occupy less space. This constitutes the *simple convoluted tubular* gland, an example of which may be seen in the sweat-glands of the skin (Fig. 686, C).

If, instead of a single invagination, secondary invaginations take place from the primary one, as in Fig. 686, D and E, the gland is then termed a compound one. These secondary invaginations may assume either a saccular or tubular form, and so constitute the two subdivisions—the *compound saccular* or *racemose* gland, and the *compound tubular*. The racemose gland in its simplest form consists of a primary invagination which forms a sort of duct, upon the extremity of which are found a number of secondary invaginations called saccules or alveoli, as in Brunner's glands (Fig. 686, D). But, again, in other instances, the duct, instead of being simple, may divide into branches, and these again into other branches, and so on; each ultimate ramification terminating in a dilated cluster of saccules, and thus we may have the secreting surface almost indefinitely extended, as in the salivary

cell-walls); the inner layer assumes the form of a prismatic epithelium, and is named the *cytoblast* (Fig. 695). These two layers form the *ectoplacenta* or *chorion*, and entirely replace the lining epithelium of the uterus where the blastodermic vesicle comes into contact with it. According to Van Beneden, the cells of the inner mass partly undergo atrophy (Fig. 694), giving rise to a cavity, limited above by the cytoblast and below by a layer of cells, which constitutes the primitive upper layer of the embryo, the *epiblast* or *ectoderm*, and which is continuous peripherally with the cytoblast. The cavity thus formed is the *primitive amniotic cavity*, and becomes the permanent amniotic cavity in man and monkeys, and in some of the bats (Fig. 695). It will thus be seen that from the inner mass of cells two layers are formed—an outer of prismatic cells, the epiblast or ectoderm, and an inner of flattened cells, the hypoblast or entoderm—and this double layer constitutes the *blastodermic membrane*, which at this stage is *bilaminar*.[1]

FIG. 696.—Embryo of a rabbit of eight days. (After Kölliker.) *ag.* Embryonic area. *pr.* Primitive streak.

3. **Formation of the Mesoblast.**—At first the area of the blastodermic membrane assumes the form of a small disk, the *germinal disk* or *germinal area*. This disk becomes oval in shape, with its more pointed end situated posteriorly. In it the first traces of the embryo are seen as a faint streak, the *primitive streak* (Fig. 696), which makes its appearance at the posterior or narrow end of the oval disk and from there gradually extends forward. The epiblast covering the primitive streak becomes indented by a groove, the *primitive groove*, the anterior end of which communicates through a canal with the yolk-sac, forming what is termed the *blastopore*. The primitive streak results from a multiplication of the cells of the epiblast, so that it becomes thickened and grows downward toward the hypoblast, which also undergoes proliferation. Together they form a thick cellular column, in which it is no longer possible to distinguish the epiblastic from the hypoblastic cells. From the sides of this column a layer of cells grows out between the epiblast and hypoblast, having been derived partly from both; this layer constitutes the *mesoblast* or *mesoderm*.

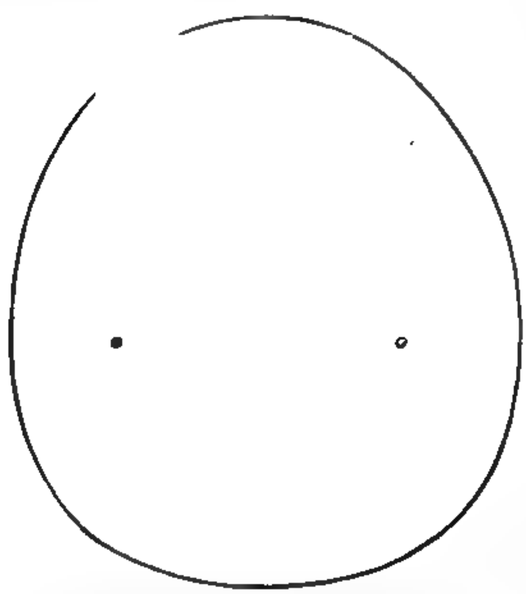

FIG. 697.—Embryonic area of the ovum of a rabbit at the seventh day. *ag.* Embryonic area. *o o.* Region of the blastodermic vesicle immediately surrounding the embryonic area. *pr.* Primitive streak. *rf.* Medullary groove. (From Kölliker.)

In this way the blastodermic membrane comes to consist of three layers, and is now known as the *trilaminar blastoderm*. Each layer has distinctive characters, the outer and inner presenting the appearance of epithelial cells, while the middle consists of a mass of branched cells without [illegible] definite arrangement. The external is termed the *epiblast*, or [illegible]ternal the *hypoblast*, or *entoderm*; and the middle, the [illegible] (Fig. 698).

[1] [illegible], articles by Van Beneden and Kollmann, *Anatomischer Anzeiger*,

remarkably curved on itself (cephalic flexure), and a smaller but similar folding-over takes place at its hinder end (caudal flexure). At the same time the sides of the embryo, formed by the somatopleure, grow and curve ventrally toward each other, so that the embryo at this stage is aptly compared to a canoe turned over, and becomes marked off from the general blastoderm by a ***limiting sulcus.*** In consequence of this incurving of the embryo, both in an antero-posterior and a lateral direction, the blastodermic vesicle becomes nipped by the somatopleure and resembles an hour-glass with two unequal parts. The smaller portion is enclosed within the body of the embryo, and constitutes the *enteron* or primitive alimentary canal, while the larger portion, left outside the embryo, is termed the ***yolk-sac*** or *umbilical vesicle.* These two parts of the original blastodermic vesicle communicate through the constricted portion, which is the site of the future umbilicus, and,

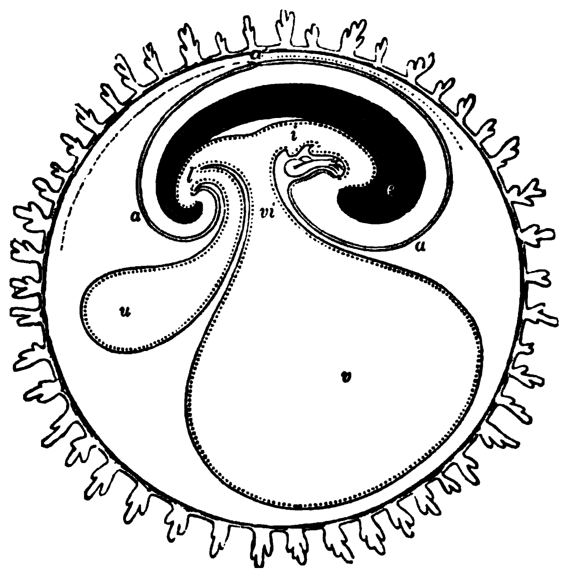

FIG. 703.—Diagrammatic action through the ovum of a mammal in the long axis of the embryo. *e.* The cranio-vertebral axis. *i, i.* The cephalic and caudal portions of the primitive alimentary canal. *a.* The amnion. *a'.* The point of reflection into the false amnion. *v.* Yolk-sac, communicating with the middle part of the intestine by *v i*, the vitello-intestinal duct. *u.* The allantois. The ovum is surrounded externally by the villous chorion.

when the body cavity is ultimately closed at the umbilicus, the constriction is narrowed to form a small duct, the *omphalo-mesenteric* or *vitelline duct* (Figs. 702, 703, and 705). The cephalic part of the primitive alimentary canal is named the *fore-gut*, the caudal portion the *hind-gut*, while the intermediate portion which communicates directly with the yolk-sac, is termed the *mid-gut.* The yolk-sac is of small importance and very temporary duration in the human subject. It is for the purpose of supplying nutrition to the embryo during the very earliest period of its existence. In the oviparous animals, however, where no supply of nourishment can be obtained from the mother, since the egg is entirely separated from her, the yolk-sac is large and of great importance, as it supplies nutrition to the chick during the whole of fœtation. Vessels developed in the mesoblast soon cover the yolk-sac, forming the *vascular* area; these are named the *omphalo-mesenteric* vessels, and are two in number (Fig. 704). They appear to absorb the fluid of the yolk-sac which, when the fluid has disappeared, dries up and has no further function. The activity of the yolk-sac ceases about the fifth or sixth week, at the same time that the allantois, which is the great bond of vascular connection between the embryo and the uterine tissues, is formed. The yolk-sac remains visible, however, up to the fourth or fifth month, with its pedicle and the omphalo-

to form the "somatopleure" and "splanchnopleure," the space between the two constituting the "cœlum" or "pleuro-peritoneal cavity." (11) The curving of the embryo on itself, both longitudinally and laterally, so as to be comparable to a canoe, part of the blastodermic vesicle being enclosed within the embryo to form the "primitive alimentary tube," part being left outside as the "yolk-sac," the two communicating by a duct, the "omphalo-mesenteric" duct. The yolk-sac provides nutrition to the embryo through the omphalo-mesenteric vessels until such time as the placenta is formed.

FORMATION OF MEMBRANES.

In order to have a clear understanding of the manner in which the embryo is developed, it is necessary at this stage to describe the development of the fœtal membranes.

The **membranes** investing the fœtus are the amnion, the chorion, and the decidua. The first two are developed from fœtal structures, and are proper to the fœtus; the last is formed in the uterus, and is derived from the maternal structures.

The Amnion.—The amnion is the innermost of the membranes which surround the embryo. It is at first of small size, but increases considerably toward the middle of pregnancy, as the fœtus acquires the power of independent movement. It exists only in reptiles, birds, and mammals, which are hence called "Amniota," but is absent in amphibia and fishes. In man, monkeys, and some of the bats, the primitive amniotic cavity, already described on page 1154, persists. In reptiles, birds, and certain mammals the amnion is formed in the following manner. At or

FIG. 705.—Diagram of a transverse section of a mammalian embryo, showing the mode of formation of the amnion. The amniotic folds have nearly united in the middle line. (From Quain's *Anatomy*, vol i, pt. i 1890.) Epiblast, - - - -; mesoblast, —·—·—, hypoblast and notochord, continuous line.

near the extremities of the incurved fœtus—that is to say, at the point of constriction of the blastodermic vesicle where the primitive alimentary canal of the embryo joins the yolk-sac—a reflection or folding backward of the somatopleure, which has become separated from the splanchnopleure by the formation of the pleuro-peritoneal cavity, takes place (Fig. 702, 2, 3). This fold commences first at the cephalic extremity, and subsequently at the caudal end and sides, and deepens more and more, in consequence of the sinking of the embryo into the blastodermic vesicle, until, gradually approaching, the different parts meet on the dorsal aspect of the embryo (Figs. 702, 10, and 705). After they come in contact

the decidua of the uterus and probably absorb from it nutritive materials for the growth of the embryo: they can be forcibly withdrawn from the decidua until the third month of pregnancy. Until about the end of the second month the villi cover the whole surface of the chorion and are of an almost uniform size, but after this they develop unequally. On that part which invades the decidua serotina they increase greatly in size and complexity, and constitute the *chorion frondosum*, which becomes the fœtal part of the placenta (Fig. 708). Over the remainder of the chorion they undergo atrophy, so that by the fourth month hardly any trace of them is left, and hence this part becomes smooth, and is therefore named the *chorion læve.* The chorionic villi are at first non-vascular, but subsequently they become vascularized by the growth into them of the allantoic mesoblast, which carries to them the branches of the allantoic arteries.

The Allantois.—The allantois grows outward as a hollow bud from the hind gut, and is therefore lined by hypoblast and covered by mesoblast (Figs. 702, 4, 5, and 703). It is projected into the space between the amnion and the chorion, and in its mesoblast are carried a pair of arteries, the *allantoic* or *umbilical arteries,* which are continued from the two primary aortæ. The allantoic mesoblast gradually spreads out on the inner surface of the chorion, and, invading the chorionic villi, supplies them with blood-vessels. In this way the allantois becomes the chief agent of the fœtal circulation, since it carries the vessels which convey the blood of the embryo to the chorion, where it is exposed to the influence of the maternal blood circulating in the decidua; from the maternal blood it imbibes the materials of nutrition and to it it gives up effete materials, the removal of which is necessary for the purification of the fœtal blood. In some animals the allantois is a hollow projection, and is usually styled the *allantoic vesicle;* but in most mammals, and especially in man, the external or mesoblastic element undergoes great development, while the internal or hypoblastic element undergoes little increase beyond the body of the embryo, so that it is very doubtful whether any cavity exists in the allantois beyond the limits of the umbilicus, or whether it does not rather consist of a solid mass of material derived from the mesoblastic tissue.[1] The proximal part of the allantoic vesicle within the body-cavity is eventually destined to form the bladder, while the remainder forms an impervious cord, the *urachus*, stretching from the summit of the bladder to the umbilicus. The part of the allantois external to the fœtus forms the umbilical cord, by which the fœtus is connected with the placenta.

The Decidua.—The growth of the chorion and placenta can be understood only by tracing the formation of the decidua.

The decidua is formed from the uterine mucous membrane before the fertilized ovum reaches the cavity of the uterus. The mucous membrane becomes vascular and tumid, its glands are greatly elongated, and their deeper portions are dilated and tortuous, while the interglandular tissue becomes crowded with epithelial-like cells (*decidual cells*). The mucous membrane, thus altered, is named the *decidua vera;* it lines the cavity of the uterus as far as the os internum, without, however, occluding the orifices of the Fallopian tubes. When the fertilized ovum reaches the uterus, which is thus prepared for its reception, it becomes attached to the decidua, in most cases in the neighborhood of the fundus uteri. The decidua then grows up around the ovum and ultimately covers it in. The part of the decidua which grows up to envelop the ovum is named the *decidua reflexa;* that portion to which the ovum originally became attached is termed the *decidua serotina*, and from it the maternal part of the placenta is derived. After conception the cervix uteri is closed by a plug of mucus (Fig. 708).

By the fourth month the decidua vera has acquired a thickness of about half

[1] Indeed, it would appear, from the researches of His, that in the human embryo the allantois is formed unusually early, being present from a very early period as a stalk of mesoblast connecting the posterior extremity of the embryo with the chorion. This stalk is termed the *abdominal stalk* (Bauchstiel).

cating blood-channels or sinuses, which are filled with maternal blood, and in which are suspended the now greatly ramified tufts of the chorionic villi. These uterine sinuses anastomose freely with one another, and form, at the edge of the placenta, a venous channel with an irregular calibre, which runs round the whole circumference of the placenta, and is termed the *marginal sinus*. Some of the chorionic villi are attached by fibrous bands to the basal layer of the decidua and to the imperfect septa between the sinuses, but the majority of them hang free.

Circulation through the Placenta.—The maternal blood is brought to the

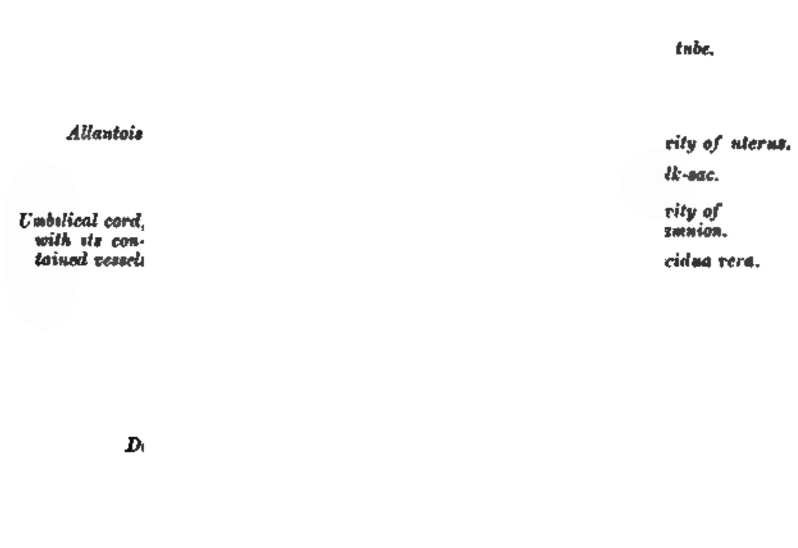

FIG. 708.—Sectional plan of the gravid uterus in the third and fourth months. (Modified from Wagner.)

uterine sinuses by the "curling arteries" of the uterus and drained away by the uterine veins, while, as already stated, within the chorionic villi are found the ramifications of the fœtal vessels derived from the allantoic or umbilical arteries. Since the villi are suspended in the sinuses, they are necessarily bathed in the maternal blood, and hence it follows that the maternal and fœtal blood-currents are brought into close relationship. There is, however, no intermingling of the two currents, or, in other words, no direct communication between the vascular system of the mother and that of the fœtus, the interchange of materials necessary for the growth of the fœtus and for the purification of the fœtal blood taking place through the walls of the villi. The purified blood is carried back to the fœtus by the umbilical vein. From what has been said, it will be understood that the placenta is the organ by which the connection between the fœtus and the mother is established, and which subserves the purposes of nutrition, respiration, and excretion.

Placenta.—At the end of the gestation period the placenta presents the form of a disk which weighs about a pound and has a diameter of from six to eight inches. Its average thickness is about an inch and a quarter, but diminishes rapidly near the circumference of the disk. Its outer or *decidual* surface blends with the uterine wall, but if examined after the separation of the placenta, it presents a comparatively smooth surface, which on inspection is seen to be incompletely divided into a number of masses named *cotyledons*. Its inner or *chorionic* surface is smooth, being closely invested by the amnion. The umbilical cord is attached near the centre of this surface, and from this attachment the larger branches of the umbilical vessels are seen radiating under the amnion. On section the placenta presents a soft, spongy appearance, caused by its freely communicating blood-

lesser wings; each of these arises by two roots, one above and one below the optic nerve, and, uniting outside the nerve, enclose the optic foramen. The base of the primitive cranium therefore consists of two parts, *prechordal* and *parachordal:* the former receives the organ of smell and is indented by the eyeball; the latter surrounds the auditory vesicle. Thus it will be seen that the bones which form the

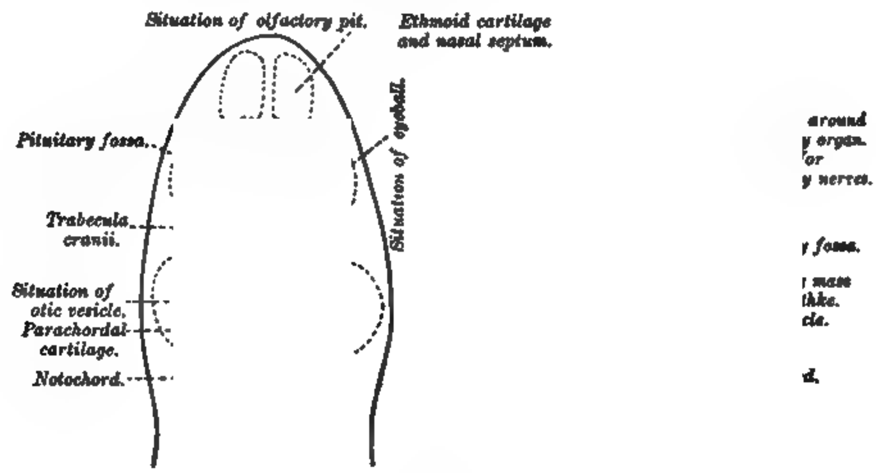

FIG. 712.—Diagrams of the cartilaginous cranium. (Wiedersheim.)

base of the skull are preceded by masses of cartilage, which together form the *chondrocranium.* Those of the vault of the skull, on the other hand, are of membranous formation, and are termed *dermal* or *covering bones.* They are developed in the mesoblast which lies superficial to the primordial cranium, or in that which lies subjacent to the epithelial lining of the foregut. They comprise the upper portion of the tabular part of the occipital (interparietal), the squamous-temporals and tympanic rings, the two parietals, the frontal, the vomer, the internal pterygoid plates, and the bones of the face. Some of them remain distinct throughout life (*e. g.*, parietal and frontal), while others join with the bones of the chondrocranium (*e. g.*, interparietal, squamous-temporal, and internal pterygoid plates).

The head at first consists simply of a cranial cavity, the face and neck being subsequently developed in the manner now to be described.

In all vertebrate animals there is at one period of their development a series of grooves in the upper neck region of the embryo. These are named the *branchial* or *visceral clefts*, and in man are four in number from before backward. They take origin as paired grooves or pouches from the side of the pharynx, and over each groove a corresponding indentation of the epiblast occurs, so that the latter comes into contact with the hypoblast lining the pharynx, and these two layers unite to form thin septa, along the bottom of the grooves, between the pharyngeal cavity and the exterior. In gill-bearing animals these septa disappear and the grooves become complete clefts, the gill clefts, opening from the pharynx on to the exterior; perforation does not, however, occur in birds and mammals. In front and behind each cleft the mesoblast becomes thickened in the form of arches, the *branchial arches* (Figs. 713, 750). In the human embryo there are five pairs of these arches, one in front of the first cleft, one behind the last, and the three remaining ones between the first and second, the second and third, and the third and fourth clefts, respectively. The first arch is named the *mandibular;* the second the *hyoid;* the third the *thyro-hyoid*, while the fourth and fifth have no distinctive names. In each arch there is developed a cartilaginous bar which gives

Before leaving the subject of the visceral arches and clefts it is necessary to mention that the clefts disappear early in embryonic life, with the exception of portions of the first, which remain permanent—the inner portion, or the Eustachian tube and tympanum; the outer, as the external auditory meatus, while the septum

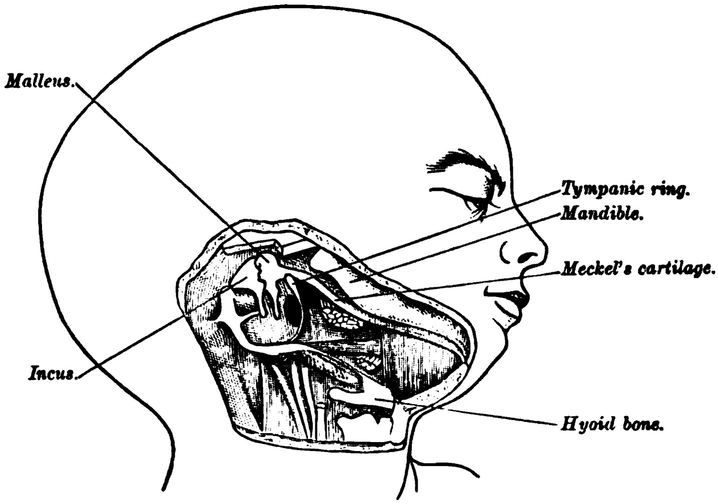

FIG. 719.—Head and neck of a human embryo eighteen weeks old, with Meckel's cartilage and hyoid bar exposed. (After Kölliker.)

between the two portions becomes invaded by mesoblast and forms the membrana tympani.

Development of the Nervous Centres and the Nerves.—The medullary or neural groove already described (page 1155) is the rudiment of the cerebro-spinal axis. As has been seen, this groove is converted into a canal (the neural canal): its cephalic end becomes dilated into a sac, from which the brain is developed; the remainder forms the spinal cord. The cavity of the canal becomes the central canal of the spinal cord, and that of the upper dilated portion the ventricles of the brain. The wall of the canal, formed of epiblastic cells, undergoes great changes, and from it the nervous matter and neuroglia are developed. It consists at first of a layer of columnar epithelium, covered on its exterior by a basement-membrane. The wall becomes thickened, partly by the elongation of the columnar cells and partly by the formation of new cells. The elongation of the columnar cells, now called *spongioblasts*, is followed by the breaking up of their outer ends into a reticulum, which is termed the *myelo-spongium*, and eventually forms the neuroglia. The new cells which are formed appear between the inner ends of the columnar cells as rounded masses, which speedily divide, and are termed *neuroblasts;* they become pear-shaped, and projecting from each of them is a tapering process which perforates the basement-membrane. These neuroblasts are the primitive nerve-cells, and their tapering processes the rudimentary axis-cylinders of the cells (Figs. 721 and 722).

It will be convenient, in the first place, to trace the changes which take place in the cavity of the cerebro-spinal axis, ignoring for a time those which go on in the enclosing wall. But before doing so, it is necessary to mention that, in consequence of the curve which the cephalic portion of the embryo undergoes, a marked bend forward of the canal takes place, so that the plane of the ventricles is almost at right angles with the long axis of the central canal of the cord.

The early stage thus consists of a hollow sac, which is the rudimentary brain, and a hollow canal, which is the rudimentary cord; the sac and the canal freely communicate with each other. The sac first of all becomes elongated; then two constrictions appear in it, which partially divide it into three; these are named *anterior*, *middle*, and *posterior cerebral vesicles*, or the *fore-brain*, *mid-brain*, and

the communication between it and the future lateral ventricle persists as the *foramen of Monro* (Fig. 725, H).

FIG. 721.—Transverse section of the spinal cord of a human embryo at the beginning of the fourth week. (After His.) The top of the figure corresponds to the lining of the central canal.

The second vesicle (*thalamencephalon*) becomes elongated from before backward and compressed laterally so as to form the greater part of the third

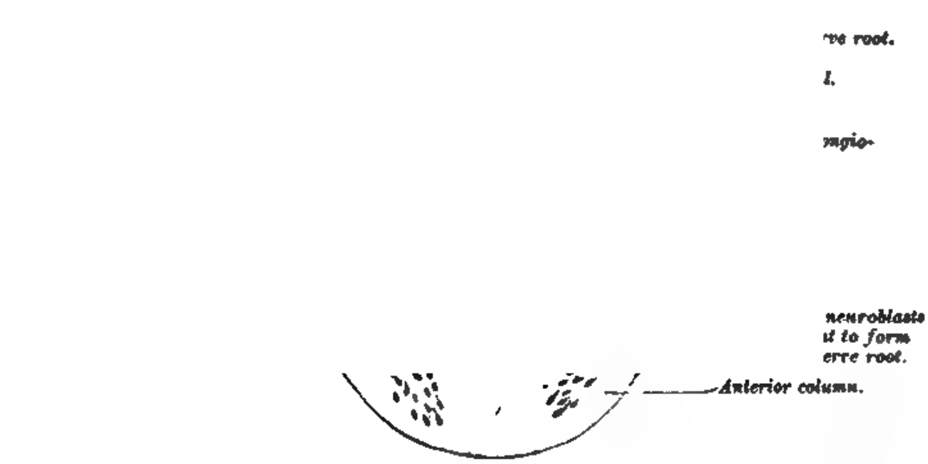

FIG. 722.—Section of spinal cord of a four weeks' embryo. (His.)

ventricle (Fig. 725, B). From each side of that part of the forebrain which ultimately becomes the second vesicle is budded off a hollow projection, the primary optic vesicle, which is developed eventually into optic nerve and retina: it will be considered later on. The constriction between the first and second vesicle disappears, so as to throw the whole of the cavity (the future third

ventricle), formed by the remains of the first vesicle and the whole of the second vesicle, into one.

The third vesicle (*mesencephalon*) is converted into a narrow channel, the *iter a tertio ad quartum ventriculum* (Fig. 725, C).

The fourth vesicle (*epencephalon*) becomes widened out, and assumes a triangular form, with its apex directed forward, and situated at the original point of constriction where the third vesicle joins the fourth. It is at the same time flattened from above downward, and constitutes the anterior half of the fourth ventricle (Fig. 725, D).

The fifth vesicle (*metencephalon*) undergoes the same change in form as the fourth, becoming triangular in shape and flattened from above downward, but with this difference, that the apex of the triangle is directed backward, and is continuous with the portion of the medullary canal which goes to form the central canal of the spinal cord (Fig. 725, E). The base is directed forward and is continuous with the base of the triangular space formed by the fourth vesicle; the constriction between the two vesicles having disappeared, the two spaces freely communicate, and together form a rhomboidal cavity which is the fourth ventricle.

6

Fig. 724.—Section of the medulla in the cervical region, at six weeks. Magnified 50 diameters. 1. Central canal. 2. Its epithelium. 3. Anterior gray matter. 4. Posterior gray matter. 5. Anterior commissure. 6. Posterior portion of the canal, closed by the epithelium only. 7. Anterior column. 8. Lateral column. 9. Posterior column. 10. Anterior roots. 11. Posterior roots.

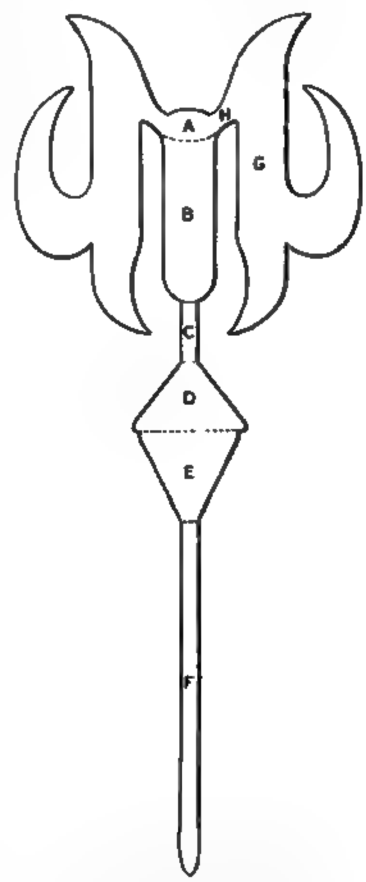

Fig. 725.—Plan showing the mode of formation of the ventricles of the brain and the central canal of the spinal cord. (After Gerrish.) A. Prosencephalon. B. Thalamencephalon. C. Mesencephalon. D. Epencephalon. E. Metencephalon. F. Central canal of cord. G. Lateral ventricle. H. Foramen of Monro.

These vesicles do not remain in the same plane, but certain definite flexures take place, which result in an alteration of the position of the vesicles to one another. The first of these flexures (*cephalic*) is opposite the base of the middle vesicle, which becomes sharply bent on itself over the end of the notochord. This has the effect of causing the mid-brain to become the most prominent part of the encephalon on the convexity of the curve (Fig. 723). A second flexure (*pontal*), with its curve in the opposite direction, takes place in the epencephalon, and is very abrupt. A third but less marked flexure (*nuchal*) takes place in the metencephalon at its junction with the cord. The first of these curves or flexures remains permanent, but the second and third almost entirely disappear in the further development of the brain.

The manner in which the different parts of the encephalon and cord are formed from the walls of this greatly altered medullary canal must now be considered, and it will be convenient first of all to study the development of the spinal cord.

as consisting of two sets: (1) those which arise as outgrowths from neuroblasts situated in the brain, similar to the mode of origin of the anterior spinal nerve-roots; (2) those which arise from ganglionic rudiments situated outside the brain and derived from the neural crest; from the neuroblasts of these ganglionic rudiments one process grows into the brain and the other outward toward the periphery, similar to the arrangement which exists regarding the posterior spinal nerve-roots. To the first group belong the third, fourth, sixth, seventh, eleventh, and twelfth nerves, together with the motor roots of the fifth, ninth, and tenth. To the second group belong the eighth and the sensory roots of the fifth, ninth, and tenth. While, however, the anterior spinal nerve-roots arise in one series from the ventral part of the cord, the cranial motor fibres arise by two sets of roots, *ventral* and *lateral;* the former include the roots of the sixth and twelfth and probably those of the third and fourth, the latter embrace the spinal accessory and the motor roots of the fifth, seventh, ninth, and tenth.

The olfactory lobe, or rhinencephalon, arises toward the end of the fourth week as a protrusion of the antero-ventral part of each cerebral hemisphere (Fig. 726), and extends forward toward the thickened epiblast of the olfactory area (see page 1169). It is subsequently divided by a transverse constriction into two parts: an anterior, which gives rise to the olfactory bulb and tract together with the trigonum olfactorium, and a posterior, which becomes the peduncle of the corpus callosum and the greater part of the anterior perforated space. Neuroblastic cells, formed within the olfactory area, pass out and form a ganglion between the area and the olfactory bulb. From this ganglion cell-processes grow centripetally to form the nerve-roots, and centrifugally to form the olfactory nerves which ramify in the olfactory mucous membrane, while the ganglion itself fuses with the olfactory bulb.

The optic nerve arises as a hollow outgrowth of the brain, which subsequently becomes solid. It will be considered in connection with the development of the eye.

The sympathetic nerves are developed as outgrowths from the ganglia on the roots of the spinal and cranial nerves.

FIG. 729.—Transverse section of head of chick embryo of forty-eight hours' incubation; × 55. (From Duval's *Atlas d'Embryologie.*)

Development of the Eye.—The optic nerve and retina are developed as an outgrowth from the rudimentary brain, which extends toward the side of the head, and is there met by an ingrowth from the epiblast, out of which the lens and the epithelium of the conjunctiva and cornea are developed.

The first appearance of the eye consists in a hollow protrusion of the fore-brain; this is called the *primitive optic vesicle.* It is at first an open cavity communicating by a hollow stalk with that of the cerebral vesicle. As it is prolonged forward, the epiblast lying immediately over it becomes thickened, and then forms a depression which gradually encroaches on the most prominent part of the primitive ocular vesicle; this in its turn appears to recede before it, so as to become at first depressed and then inverted in the manner indicated

oped from the "neural crest" in the manner above described (page 1180), pierces the auditory capsule in two main divisions—one for the vestibule, the other for the cochlea. The middle ear and Eustachian tube are the remains of the inner part of the first branchial cleft (hyomandibular), and are closed externally by the membrana tympani, which originally consists of a layer of epiblast externally, and a layer of hypoblast internally; between these two layers the mesoblast extends to form the substantia propria of the membrane. With regard to the exact mode

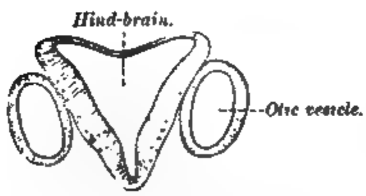

FIG. 736.—Section through hind-brain and otic vesicle of an embryo more advanced than that of Fig. 735. (After His.)

Recessus labyrinthi (aquæductus

vesicle.

FIG. 737.—Left auditory vesicle of a human embryo of four weeks, seen from the outer surface. (W. His, Jr.)

of development of the ossicles of the middle ear there is considerable difference of opinion. The most probable view is that the *incus* and *malleus* are developed from the proximal end of the mandibular (Meckel's) cartilage (Fig. 719): that the base of the *stapes* is formed by the ossification of the cartilage which fills in the foramen ovale and its arch from the ossified proximal end of the hyoidean arch.

The external auditory meatus is formed from the outer part of the hyo-

Recessus la

Superior semicircular

semi-
r canal.
ternal semi-
ircular canal.

Rudiment of cochlea.

FIG 738.—Left auditory vesicle of a human embryo of five weeks, seen from the outer surface. (W. His, Jr.)

mandibular cleft, while the pinna is developed by the gradual differentiation of a series of processes which appear around the outer margin of the cleft (Fig. 741).

Development of the Nose.—The olfactory fossæ, like the primary auditory vesicles, are formed in the first instance by a thickening and involution of the epiblast, which takes place about the fourth week, at a point below and in front of the ocular vesicle (Fig. 723). The borders of the involuted portion very soon become prominent, in consequence of the development of the mesial and lateral nasal processes already referred to (page 1169), and which are formed on either side of the rudimentary fossa (Figs. 714, 715). As these processes increase, the fossa deepens

Development of the Skin, Glands, and Soft Parts.—The epidermis and its appendages, consisting of the hairs, nails, sebaceous and sweat glands, are developed from the epiblast, while the corium or true skin is of mesoblastic origin. About the fifth week the epidermis consists of two layers of cells, the deeper one corresponding to the rete mucosum. The subcutaneous fat forms about the fourth month, and the papillæ of the true skin about the sixth. A considerable desquamation of epidermis takes place during fetal life, and this desquamated epidermis, mixed with a sebaceous secretion, constitutes the *vernix caseosa*, with which the

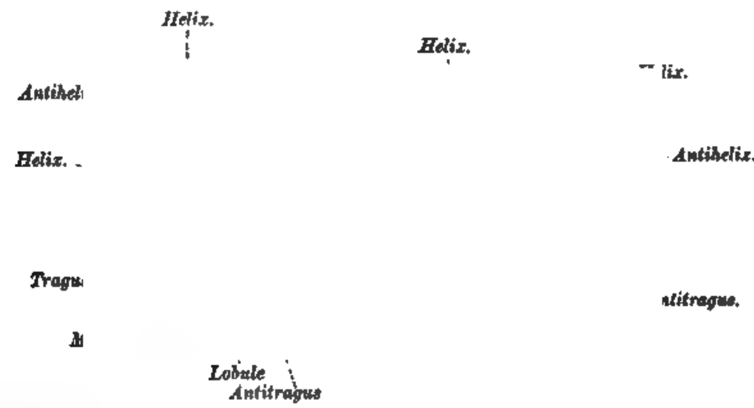

FIG. 741.—Left ears of human embryos, estimated at thirty-five and thirty-eight days respectively (After His.)

skin is smeared during the last three months of fetal life. The nails are formed at the third month, and begin to project from the epidermis about the sixth. The hairs appear between the third and fourth months in the form of solid downgrowths of the deeper layer of the epidermis, which then become inverted by papillary projections from the corium. About the fifth month, the fetal hairs (*lanugo*) appear, first on the head and then on the other parts; they drop off after birth. and give place to the permanent hairs. The cellular structure of the sudoriferous and sebaceous glands is formed from the epiblast, while the connective tissue and

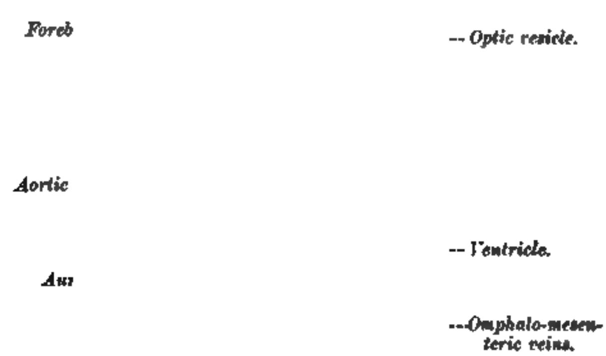

FIG. 742.—Head of chick embryo of about thirty-eight hours' incubation, viewed from the ventral surface (From Duval's *Atlas d'Embryologie.*)

blood-vessels are derived from the mesoblast. The mammary gland is also formed partly from mesoblast and partly from epiblast—its blood-vessels and connective tissue being derived from the former, its cellular elements from the latter. Its first rudiment is seen about the third month, in the form of a small projection inward of epithelial elements, which invade the mesoblast; from this, similar tracts of cellular elements radiate; these subsequently give rise to the glandular

auricle, and is formed by the union of three pairs of veins, viz., (1) the veins or ducts of Cuvier from the body of the embryo; (2) the omphalo-mesenteric veins from the yolk-sac; (3) the umbilical veins from the placenta (Fig. 747). The sinus is at first placed transversely, and opens by a median aperture into the common auricle. Soon, however, it assumes an oblique position, and its right half or horn becomes larger than the left, while the opening into the auricle is found to be in the right portion of the auricular cavity. The right horn ultimately becomes incorporated with and forms a part of the right auricle, the line of union between it and the auricle proper being indicated in the interior of the adult auricle by a vertical crest, the *crista terminalis* of His. The left horn, which ultimately receives only the left duct of Cuvier, persists as the coronary sinus (Fig. 753). The omphalo-mesenteric and umbilical veins are soon replaced by a single vessel, the inferior vena cava, and the three veins (inferior vena cava and right and left Cuvierian ducts) open into the dorsal aspect of the auricle by a common slit-like aperture. The upper part of this aperture represents the opening

Left vent

vena cava.

ransversum.

l vein.

Vitelline or Omphalo-mesenteric vein.

FIG. 747.—Heart of a human embryo 4.2 mm. in length, seen from behind. (His.)

of the permanent superior vena cava, the lower part that of the inferior vena cava, and the intermediate part the orifice of the coronary sinus. The slit-like aperture lies obliquely, and is bordered on its mesial and lateral aspects by a fold of endocardium. The mesial part of the fold disappears, while from the lateral part the Eustachian and Thebesian valves are developed. At the lower extremity of the slit is a triangular thickening, the *spina vestibuli* of His, which partly closes the aperture between the two auricles, and which, according to His, takes a part in the formation of both the interauricular and interventricular septum.

The common auricle becomes gradually subdivided into right and left auricles by a septum, the *septum superius*, which grows from its dorsal and upper wall so that the two auricles communicate with each other only below the margin of this septum. This communication (*ostium primum* of Born) does not, however, represent the future foramen ovale, for the septum grows downward and blends with the partition which comes to subdivide the auricular canal. The foramen ovale (*ostium secundum* of Born) results from a perforation of the upper part of the septum superius.

The auricular canal is at first a short straight tube connecting the auricular with the ventricular portion of the heart, but it becomes overlapped by the growing auricles and ventricles so that its position on the surface of the heart is indicated only by an annular constriction (Fig. 746). Its lumen is reduced to a transverse slit, and a thickening appears on its dorsal and ventral walls. These thickenings, or *endocardial cushions* as they are termed, project into the canal, and, meeting in the middle line, divide the canal into two channels, the future right and left auriculo-ventricular orifices.

The common ventricle becomes divided by a septum, the *septum inferius*, which

Development of the Veins.—The formation of the great veins of the embryo may be best considered under two groups, visceral and parietal.

The *visceral veins* are the two vitelline or omphalo-mesenteric veins bringing the blood from the yolk-sac, and the two umbilical or allantoic veins returning the blood from the placenta; these four veins open close together into the sinus venosus (Fig. 747).

The vitelline veins run upward at first in front, and subsequently on either side of the intestinal canal. They unite on the ventral aspect of the canal before they reach the liver, and then encircle the intestinal tube by forming around it two venous rings, the first on its dorsal, the second on its ventral aspect. The portions of the veins above the upper ring become invaded by the developing

FIG. 752.—Showing the destination of the arterial arches in man and mammals. (Modified from Rathke.) (From Quain's *Anatomy*, 1890, vol. i., pt. 1.) The truncus arteriosus and the five arterial arches springing from it are represented in outline only; the permanent vessels in shade—those belonging to the aortic system in heavy shaded line, to the pulmonary system in light shaded line.

liver and broken up by it into a network of smaller vessels, the central part of the network consisting of a capillary plexus. The branches which convey the blood to this plexus are named the *venæ advehentes*, and become the branches of the portal vein; while the vessels which drain the plexus into the sinus venosus are termed the *venæ revehentes*, and form the future hepatic veins (Figs. 753 and 754).

The lower part of the *portal vein* is formed from the fused vitelline veins which receive the veins from the alimentary canal; its upper part is derived from the venous rings by the persistence of the left half of the lower and the right half of the upper ring, so that the vessel forms a spiral turn round the duodenum (Fig. 754).

The two umbilical veins fuse early to form a single trunk in the allantois, but remain double for some time in the embryo and pass forward to the sinus venosus in the side walls of the body. Like the vitelline veins, their direct connection with the sinus venosus becomes interrupted by the invasion of the liver, and thus at this stage the whole of the blood from the yolk-sac and placenta passes through the substance of the liver before it reaches the heart. The right umbilical vein

sinus, as has been indicated, represents the persistent left horn of the sinus venosus. The primitive jugular veins become the internal jugular veins of the adult; the lower part of the right primitive jugular vein forms also the right innominate veins (Figs. 755, 1, 2, 3).

The fœtal circulation has been described in the section on the Blood-Vascular System.

Development of the Alimentary Canal.—As already indicated (page 1157), the primitive alimentary canal is formed, at an early stage, by the enclosure within the embryo of a portion of the blastodermic vesicle, and is seen to consist of three parts, viz.: (1) the *fore-gut*, within the cephalic flexure and dorsal to the heart; (2) the *mid-gut*, opening freely into the yolk-sac; and (3) the *hind-gut*, within the caudal flexure. The fore-gut and hind-gut end blindly, there being at first neither mouth nor anus (Figs. 756 and 757). The formation of the mouth or stomodæum, and the subsequent communication between it and the cephalic end of the fore-gut, have already been considered; the manner in which the anus is formed will presently be discussed.

FIG. 758.—Early form of the alimentary canal. (From Kölliker, after Bischoff.) In A a front view and in B an antero-posterior section are represented. *a*. Four pharyngeal or visceral plates. *b*. The pharynx. *c*, *c*. The commencing lungs. *d*. The stomach. *f*, *f*. The diverticula connected with the formation of the liver. *g*. The yolk-sac into which the middle intestinal groove opens. *h*. The posterior part of the intestine.

From the fore-gut are developed the pharynx, œsophagus, stomach, and duodenum, and further, as diverticula from the duodenum, the liver and pancreas; from the hind-gut, the greater part of the rectum, and as a tubular outgrowth from it the hollow stalk of the allantois; the mid-gut gives origin to the remainder, or longest section, of the alimentary tube—*i. e.*, the portion which reaches from the duodenum to the rectum.

The upper part of the fore-gut becomes dilated to form the pharynx, in relation to which the branchial arches are developed (Figs. 716 and 759); the succeeding part remains tubular, and with the descent of the stomach is elongated to form the œsophagus. Soon a fusiform dilatation, the future stomach, makes its appearance, and beyond this the mid-gut opens freely into the yolk-sac (Figs. 759 and 760).

This opening is at first wide, but, as the body-walls close in around the umbilicus, it is gradually narrowed into a tubular stalk, the *yolk-stalk* or *vitello-intestinal duct*. At this stage, therefore, the alimentary canal forms a nearly straight tube in front of the notochord and primitive aortæ (Fig. 757). From the stomach to the rectum it is attached to the notochord by a band of mesoblast, from which the common mesentery of the gut is subsequently developed. The stomach undergoes a further dilatation, and its two curvatures can be recognized (Figs. 760 and 764), the greater directed toward the vertebral column and the lesser toward the anterior wall of the abdomen, while of its two surfaces one looks to the right and the other to the left. The mid-gut also undergoes great elongation, and forms a V-shaped loop which projects downward and forward; from the bend or angle of the loop the vitello-intestinal duct passes to the umbilicus (Fig. 764). For a time a part of the loop extends beyond the abdominal cavity into the umbilical cord, but by the end of the third month this is withdrawn. With the lengthening of the tube, the mesoblast, which attaches it to the future vertebral column and which carries the blood-vessels for the supply of the gut, is

The gut now becomes rotated upon itself, so that the large intestine is carried over in front of the small intestine, and the cæcum is placed immediately below

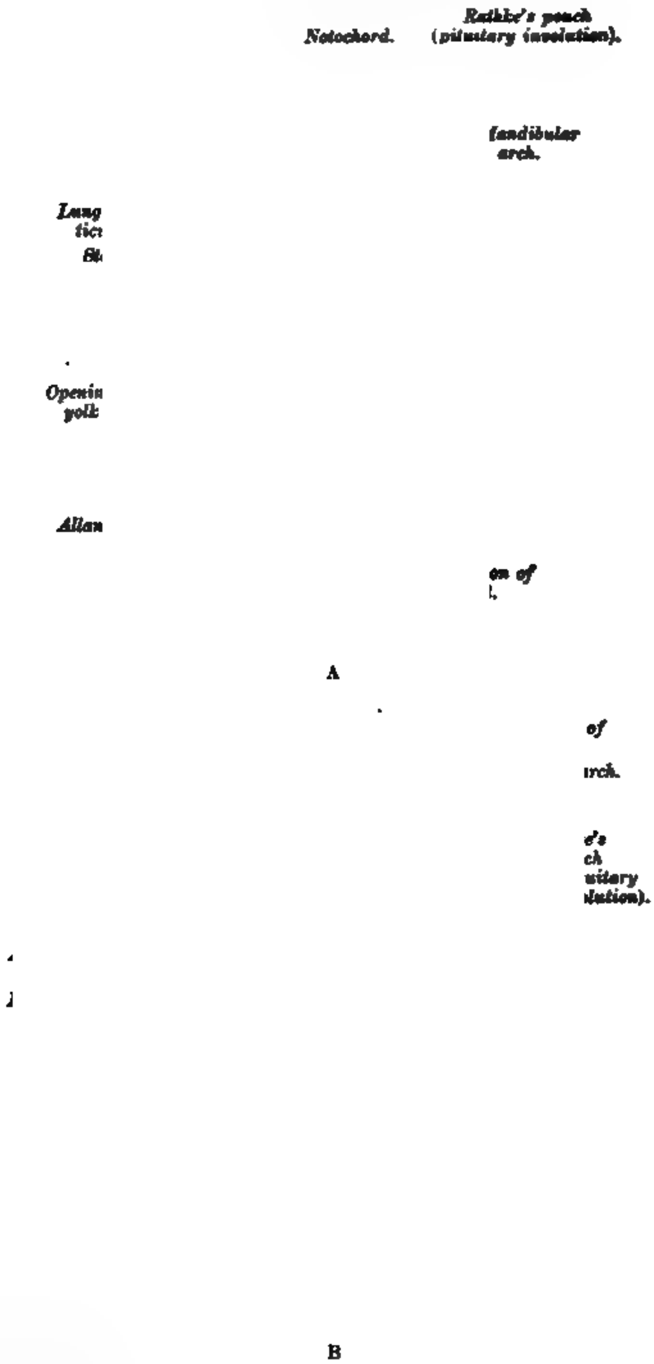

FIG. 760.—Sketches in profile of two stages in the development of the human alimentary canal. (His.) Fig. A × 30. Fig. B × 20.

the liver; about the sixth month the cæcum descends into the right iliac fossa. and the large intestine now forms an arch consisting of the ascending, transverse. and descending portions of the colon—the transverse portion crossing in front

Th
over i

The *liver* arises in the form of two diverticula or hollow outgrowths from the ventral surface of that portion of the fore-gut which afterward becomes the

FIG. 768.—Schematic figure of the bursa omentalis, etc. Human embryo of eight weeks. (Kollmann.)

duodenum (Figs. 759, 760). The outgrowths, which represent the right and the left lobes, respectively, of the adult liver, give off solid buds of cells, which grow into columns or cylinders: these unite with one another in every direction to form a close network, in the meshes of which are contained the capillary blood-vessels. Some of these columns become hollowed out and form the bile-ducts, while the

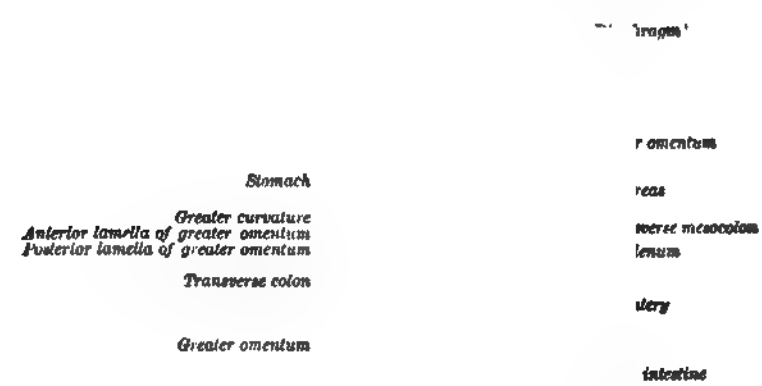

FIG. 769.—Illustrating the development of the bursa omentalis, cavity of the great omentum or lesser sac. Fœtal stage. * Lesser sac. (Hertwig.)

remainder constitute the secreting structure. The minute ducts thus produced unite to form the right and left hepatic ducts; while the common bile-duct is developed as a protrusion from the duodenal wall, and as it grows the liver becomes shifted away from the duodenum. The gall-bladder and cystic duct are formed by a hollow evagination from the wall of the common bile-duct. About the third month the liver almost fills the abdominal cavity. From this period the relative development of the liver is less active, more especially that of the left lobe, which

connection between the intestinal cavity and the substance of this organ. It originates in the mesenteric fold which connects the stomach to the vertebral column (mesogastrium) (Fig. 764).

The thyroid body is developed as a median and two lateral diverticula from the ventral wall of the pharynx. The median diverticulum appears first; it commences at the foramen cæcum, between the anterior and posterior rudiments of the tongue, and extends backward as a tubular duct, the ***ductus thyro-glossus.*** The lateral diverticula arise from the fourth visceral cleft and fuse with the median

Papillary portion of tongue.

arch.

of tongue.

FIG. 773.—Floor of mouth of an embryo slightly older than that shown in Fig. 772. × 16. (From His.)

part to form the thyroid body. The connection of the lateral diverticula with the pharynx disappears early, but the remains of the ductus thyro-glossus may persist as a tube leading from the foramen cæcum toward the hyoid bone, the ***pyramid*** of the thyroid probably representing its lower part.[1]

The thymus is developed from bilateral diverticula, which are principally derived from the third visceral cleft. It increases in size until the second year of life, after which it undergoes atrophy.

Development of the Respiratory Organs.—The lungs appear somewhat later than the liver. They are developed from a small median *cul-de-sac* or diverticulum from the upper part of the fore-gut, immediately behind the fourth visceral cleft. During the fourth week a pouch is formed on either side of the central diverticulum, and opens freely through it into the fore-gut (pharynx). These lateral pouches soon become subdivided—the right into three and the left into two parts, these subdivisions being the early indications of the lobes of the lungs (Figs. 716 and 761). The two primary pouches have thus a common tube of communication with the pharynx. This common tube becomes the larynx and trachea, the latter rapidly elongating as development proceeds. The larynx first becomes evident as a dilatation of the upper part of the trachea about the end of the fifth week. The epiglottis is developed from the anterior or median portion of the furcula, and the aryteno-epiglottidean folds from its lateral ridges (Fig. 772). The vocal cords and ventricles of the larynx are formed about the fourth month.

As the lungs grow backward they project into the anterior part of the cœlum, which becomes shut off from the rest of the body-cavity by the pericardium and Diaphragm to form the pleural cavities.

The Diaphragm is formed in two parts: (*a*) ventral, (*b*) dorsal. The ventral part appears first, and consists of a thick septum of mesoblast, the ***septum transversum,*** which projects from the anterior and lateral walls of the embryo, and which ends behind in a free edge. The sinus venosus, which receives the vitelline, umbilical, and Cuvierian veins is placed originally in this septum, and into the posterior part of it also the liver diverticula grow from the duodenum. The sinus separates itself above from the septum, and the greater part of it is incorporated with the right auricle. The liver also becomes separated from it below, except where the veins pass through into the heart. The septum transversum shuts

[1] Kanthack (*Journal of Anat. and Physiol.*, vol. xxv., p. 155) disputed this view. He examined 100 subjects, 60 of which were fœtuses or infants, and found that in many cases there was no trace of foramen cæcum and that, when it was present, it formed a short canal near the surface and was lined with stratified squamous, not columnar, epithelium. Further, after careful microscopical examination he found no trace of a tubular lumen in the pyramid of the thyroid body.

or *pronephros* (Lankester), and is a very rudimentary organ which speedily disappears. Behind this body and to the inner side of the Wolffian duct, between it and the body-cavity, a number of tubes are formed, which communicate by one extremity with the Wolffian duct, and, passing transversely toward the body-cavity, terminate in cæcal extremities. These tubes are called segmental tubes, and the whole mass is known as the *mid-kidney*, *Wolffian body*, or *mesonephros* (Lankester) (Fig. 775). After a time the cæcal extremities become dilated and enclose a tuft or glomerulus of capillary blood-vessels. As soon as the permanent kidneys are formed, the Wolffian body for the most part disappears. In the male, however, the vasa efferentia and rete testis of the testicle are formed as outgrowths from it. In the female traces of it are left as the *parovarium* and *epoöphoron*. In the male the Wolffian duct becomes the epididymis and vas deferens; in the female it undergoes atrophy, and is represented only by the functionless duct of Gärtner.

Finally, in that portion of the intermediate cell-mass which lies behind the Wolffian body, a differentiation of cells takes place which results in the formation of a number of convoluted tubes; into this a hollow protrusion of the lower end of the Wolffian duct grows up, and thus is formed the *hind-kidney* or *metanephros* (Lankester). This is the permanent kidney. The uriniferous convoluted tubes and Malpighian corpuscles are formed from the intermediate cell-mass, and the collecting tubules and ureter from the protrusion from the posterior end of the Wolffian duct.

Shortly after the formation of the Wolffian body, a second duct becomes developed. It arises on the outer side of this body as a slight thickening of the cells lining the pleuro-peritoneal cavity. This thickening then becomes invaginated into the mesoblast and extends as a cord along the outer side of the Wolffian body, to the posterior extremity of the embryo. It speedily acquires a lumen, and is then known as the *Müllerian duct* (Fig. 774). In its passage to the posterior extremity of the embryo it comes into close relation with the Wolffian duct, and the two ducts on either side become connected with their fellows on the opposite side by their cellular substance into a single cord, the *genital cord* (Fig. 776, *g. c*), in which the Wolffian ducts lie side by side in front, and the ducts of Müller behind. These latter tubes in the substance of the genital cord become fused together, and open by a single orifice into the hind-gut (cloaca). At their anterior extremities the ducts of Müller open by a somewhat funnel-shaped orifice into the pleuro-peritoneal cavity. In the female the greater part of the Müllerian duct is developed into the Fallopian tube, but the posterior fused portion of the two ducts is converted into the uterus and vagina (Fig. 777). In the male the greater part of the ducts disappears; the posterior fused portion is believed to be represented by the *sinus pocularis* (*uterus masculinus*) of the urethra.

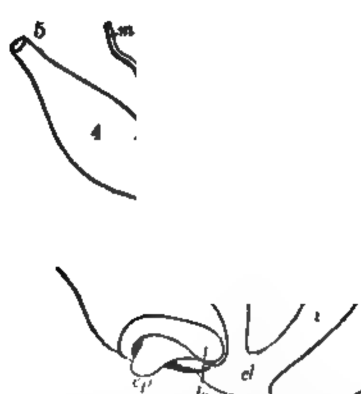

FIG. 776.—Diagram of the primitive urogenital organs in the embryo previous to sexual distinction. The parts are shown chiefly in profile, but the Müllerian and Wolffian ducts are seen from the front. 3. Ureter. 4. Urinary bladder. 5. Urachus. *ot*, The mass of blastema from which ovary or testicle is afterward formed. *W*, Left Wolffian body. *w, w*, Right and left Wolffian ducts. *m, m*, Right and left Müllerian ducts uniting together and with the Wolffian ducts in *gc*, the genital cord; *sg*, Sinus urogenitalis. *i*, Lower part of the intestine. *cl*, Common opening of the intestine and urogenital sinus. *cp*, Elevation which becomes clitoris or penis. *ls*, Ridge from which the labia majora or scrotum are formed.

It has been seen that the Wolffian and Müllerian ducts open into the common cloaca, which is the termination of the intestinal cavity, and into which the allantois also opens in front (Fig. 776). As the allantois expands into the urinary bladder this common cavity is divided into two by a septum, to form the urogenital sinus in front and the

The ovary, thus formed from the genital ridge, consists of a central part of connective tissue covered by a layer or layers of epithelium, the *germinal epithelium*. Columns of this epithelium, termed *egg-tubes*, grow down into the stroma, and simultaneously with this an upward growth of the connective tissue takes place between the columns of epithelial cells. It results from this that the columns of cells become enclosed in meshes of connective tissue (Fig. 784). Each egg-tube or nest represents a primitive Graafian follicle, one cell of which becomes enlarged to form the ovum; the remainder form the epithelium of the follicle. The remains of the germinal epithelium on the surface of the ovary form the permanent epithelial covering of this organ. According to Beard, the primitive ova are early set apart during the segmentation of the ovum and migrate into the germinal ridge.

The testicle is developed in a very similar way to the ovary, but the processes are not so well marked. Like the ovary, in its earliest stages it consists of a central mass of connective tissue covered by germinal epithelium. A downward growth of columns of this epithelium into the central connective tissue takes place. From these the seminiferous tubules are developed and become connected with outgrowths from the Wolffian body, which, as before mentioned, form the rete testis and vasa efferentia.

With regard to the other parts of the internal female organs, the Fallopian tube, as has been mentioned, is developed from the upper part of the duct of Müller, while the lower parts of the two ducts approach each other, and, lying

FIG. 778.—Adult ovary, parovarium, and Fallopian tube. (From Farre, after Kobelt.) *a, a.* Epoöphoron formed from the upper part of the Wolffian body. *b.* Remains of the uppermost tubes sometimes forming hydatids. *c.* Middle set of tubes. *d.* Some lower atrophied tubes. *e.* Atrophied remains of the Wolffian duct. *f.* The terminal bulb or hydatid. *h.* The Fallopian tube, originally the duct of Müller. *i.* Hydatid attached to the extremity. *l.* The ovary.

side by side, finally coalesce to form the cavity of the uterus and vagina. This coalescence commences in the middle of the genital cord, and corresponds to the body of the uterus. With regard to the further changes in the female organs, the only remains of the Wolffian body in the complete condition are two rudimentary or vestigial structures, which can be found, on careful search, in the broad ligament near the ovary: the *parovarium* or *organ of Rosenmüller* and the *epoöphoron* (Fig. 778). The organ of Rosenmüller consists of a number of tubes which converge to a transverse portion, the epoöphoron, and this is sometimes prolonged into a distinct duct, running transversely, the *duct of Gärtner*, which is much more conspicuous and extends further in some of the lower animals. This, as has been pointed out, is the remains of the Wolffian duct. About the fifth month an annular constriction marks the position of the neck of the uterus, and after the sixth month the walls of the uterus begin to thicken. The round ligament is derived from a band containing involuntary muscular fibres, which runs downward from the lower part of the Wolffian body to the groin, and which in

between the third and fourth month. A similar involution of epithelium to that which in the female forms the glands of Bartholin takes place in the male and becomes the glands of Cowper.

The following table is translated from the work of Beaunis and Bouchard, with some alterations, especially in the earlier weeks. It will serve to present a *résumé* of the above facts in an easily accessible form.[1]

[1] It will be noticed that the time assigned in this table for the appearance of the first rudiment of some of the bones varies in some cases from that assigned in the description of the various bones in the sequel. This is a point on which anatomists differ, and which probably varies in different cases.

Ninth Week.—The corpus striatum and the pericardium are first apparent. The ovary and testicle can be distinguished from each other. The genital furrow appears. The osseous nuclei of the bodies and arches of the vertebræ, of the frontal, vomer, and malar bones of the shafts of the metacarpal and metatarsal bones, and of the phalanges appear. The union of the hard palate is completed. The gall-bladder is seen.

Third Month.—The formation of the fœtal placenta advances rapidly. The projection of the caudal extremity disappears. It is possible to distinguish the male and female organs from each other. The cloacal aperture in divided into two parts. The cartilaginous arches on the dorsal region of the spine close. The points of ossification for the occipital, sphenoid. lachrymal, nasal, squamous portion of temporal and ischium appear, as well as the orbital centre of the superior maxillary. The pons Varolii and fissure of Sylvius can be made out. The eyelids, the hair, and the nails begin to form. The mammary gland, the epiglottis, and prostate are beginning to develop. The union of the testicle with the canals of the Wolffian body takes place.

Fourth Month.—The closure of the cartilaginous arches of the spine is complete. Osseous points for the first sacral vertebra and os pubis appear. The ossification of the malleus and incus takes place. The corpus callosum, the membrana lamina spiralis, the cartilage of the Eustachian tube, and the tympanic ring are seen. Fat is first developed in the subcutaneous cellular tissue. The tonsils are seen, and the closure of the genital furrow and the formation of the scrotum and prepuce take place.

Fifth Month.—The two layers of the decidua begin to coalesce. Osseous nuclei of the axis and odontoid process, of the lateral points of the first sacral vertebra, of the median points of the second, and of the lateral masses of the ethmoid make their appearance. Ossification of the stapes and the petrous bone and ossification of the germs of the teeth take place. The germs of the permanent teeth and the organ of Corti appear. The eruption of hair on the head commences. The sudoriferous glands, Brunner's glands, the follicles of the tonsil and base of the tongue, and the lymphatic glands appear at this period. The differentiation between the uterus and vagina becomes apparent.

Sixth Month.—The points of ossification for the anterior root of the transverse process of the seventh cervical vertebra, the lateral points of the second sacral vertebra, the median points of the third, the manubrium sterni and the os calcis appear. The sacro-vertebral angle forms. The cerebral hemispheres cover the cerebellum. The papillæ of the skin, the sebaceous glands, and Peyer's patches make their appearance. The free border of the nail projects from the corium of the dermis. The walls of the uterus thicken.

Seventh Month.—The additional points of the first sacral vertebra, the lateral points of the third, the median point of the fourth, the first osseous point of the body of the sternum, and the osseous point for the astragalus appear. Meckel's cartilage disappears. The cerebral convolutions, the island of Reil, and the tubercula quadrigemina are apparent. The pupillary membrane atrophies. The testicle passes into the vaginal process of the peritoneum.

Eighth Month.—Additional points for the second sacral vertebra, lateral points for the fourth and median points for the fifth sacral vertebræ, can be seen.

Ninth Month.—Additional points for the third sacral vertebra, lateral points for the fifth, osseous points for the middle turbinated bone, for the body and great cornu of the hyoid, for the second and third pieces of the body of the sternum, and for the lower end of the femur appear. Ossification of the bony lamina spiralis and axis of the cochlea takes place. The eyelids open, and the testicles are in the scrotum.

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